

The University of Chicago

VEGETATION OF THE GREAT SALT
LAKE REGION

A DISSERTATION SUBMITTED TO THE
FACULTY OF THE DIVISION OF THE
BIOLOGICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF BOTANY

1932

By
SEVILLE FLOWERS

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VEGETATION OF THE GREAT SALT LAKE REGION
CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 450

SEVILLE FLOWERS

(WITH ONE FIGURE)

Origin of Great Salt Lake

Great Salt Lake is located in northwestern Utah and is the remnant of Lake Bonneville, a great body of fresh water extant in Pleistocene times. At its highest level the ancient lake stood about 1000 feet above the present level of Great Salt Lake. A slight rise in level caused it to overflow its rim at a point since known as Red Rock Pass, Idaho. The outlet was eroded at a rapid rate with the subsequent lowering of the lake level. Erosion continued for 375 feet, when a large mass of hard rock was encountered. At this time the lake is believed to have had a longer period of constant level than at any other period in its history. Further decline of the lake was due to evaporation. At a point 200 feet above the present level of Great Salt Lake, alkaline salts began to concentrate and were deposited in the sediments. Evidences of the extinct lake are manifested mainly in the terraces and alluvial fans high along the bases of the mountains. Two large terraces are very prominent, the Bonneville terrace, which marks the highest level, and the Provo terrace, which was formed when the rapid erosion of the outlet became arrested.

Physiography and geology

The topography of the region presents a series of parallel mountain ranges and valleys extending north and south, and cut diag-

onally by a series of passes so as to impart a somewhat latticed design to the region as a whole. Great Salt Lake occupies an area of coalescence of valleys and passes. To the east of the lake the Wasatch Mountains rise and constitute one of the principal watersheds of the basin. The Oquirrh and Stansbury mountains are short ranges lying directly south of the lake.

The greatest extent of the lake shore is bordered by lowlands. The valley floors are composed of lacustrine sediments dominated by clays and loams. The depth of the valley fill has not been determined definitely, but wells have been sunk to a depth exceeding 2000 feet and the deposits have been found to be remarkably similar, both vertically and horizontally. Extending from the lake the following soil series is recognized: Great Salt Lake sand, Jordan clay, Jordan sand, Jordan sandy loam, Jordan loam, Bingham loam, and Bingham gravelly loam. The Jordan series is notably alkali-bearing.

The mountains rise abruptly from the floor of the valley in many places, but long alluvial slopes, called bajadas, extend for 1 to 5 miles, gradually rising to an elevation of nearly 1550 feet above the bottom of the valley. Old lake terraces high along the bases of the mountains are a conspicuous topographical feature.

Practically all of the permanent streams reaching the lake arise to the east. Three rivers, the Bear, Weber, and Jordan, carry the greatest amount of drainage water. Numerous smaller streams enter directly. The southern, western, and northern sections contribute almost no surface water other than flood run-off. Springs are common along the bases of the mountains and along the lake shore, while permanent wells have been sunk at various points.

Climate

Precipitation and temperature data were taken from representative stations surrounding the lake. Additional data were obtained from other stations. Stations located near the base of high mountains show the highest average rainfall while the valley and desert stations show the lowest amounts. Corinne, Ogden, Farmington, and Saltair are located on the eastern side of the lake, Midlake is on the Southern Pacific Railroad trestle in the middle of the lake, Kelton is located at the northwestern extremity 7 miles from the shore, and

Lemay is 20 miles west of the lake on the Great American Desert. The eastern section averages between 16 and 17 inches of rain per year, Farmington showing the highest annual mean of 20.67 inches and Corinne showing the lowest mean with 12.56 inches. The annual precipitation of the western section averages about 5.0 inches. Midlake shows 5.39 inches. Assuming that the data from these stations approach the averages of each section, there is about 10 inches difference between the western and eastern sides of the lake. The mean annual rainfall data are included in table I. Fragmentary data show

TABLE I
MEAN ANNUAL PRECIPITATION, TEMPERATURE DATA, AND LENGTH
OF GROWING SEASON FROM GREAT SALT LAKE REGION

STATION	PRECIPITATION (INCHES)	TEMPERATURE (°F.)	LENGTH OF GROWING SEASON (DAYS)
Farmington.....	20.67	49.8	
Ogden.....	15.20	52.2	154
Corinne.....	12.56	50.4	
Saltair.....	14.51	50.7	193
Kelton.....	6.44	48.4	108
Lemay.....	4.32	51.1	174
Midlake.....	5.39	52.2	225

that the annual average for the mountains above 9000 feet elevation amounts to something between 28 and 40 inches. This is significant, as the contribution to the lake by way of streams depends upon the rainfall in the higher ranges.

The mean annual temperatures of the region show little variation and range from 48.4° to 52.2° F. The same stations furnished this datum as shown in table I.

There is a wide variation in the dates of the last killing frost in the spring and the first killing frost in the autumn. The averages of the dates recorded at each station furnish the approximate length of the growing season as shown in table I.

The only station within range of the lake where records of the relative humidity have been kept is located in Salt Lake City. The daily variation is very wide in the summer, ranging from 46% at 6:00 A.M. to 26% at 6:00 P.M. Table II shows the average monthly and annual percentages. Evaporation and wind movement data (table III)

were obtained from Midlake and Lehi, the latter station being located 25 miles south of Great Salt Lake.

According to the records taken in Salt Lake City, the sun shines 62.4% of the time possible for it to do so. The heaviest average amount occurs in July, with 80%. The average wind velocity in Salt Lake City is 7.8 miles per hour; the prevailing direction is southwest. The averages recorded here are taken from the records of the

TABLE II
AVERAGE MONTHLY AND ANNUAL HUMIDITY PERCENTAGES COVERING
31 YEARS IN SALT LAKE CITY

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
6 A.M.	75	73	65	69	57	50	46	46	49	58	65	73	59.7
6 P.M.	70	64	50	39	36	28	26	26	32	45	58	69	45.2

TABLE III
AVERAGE MONTHLY AND SEASONAL EVAPORATION IN INCHES AND
WIND MOVEMENT IN MILES

	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	SEASON
Lehi									
Evaporation....	5.533	8.583	9.957	10.412	9.455	6.776	3.887	1.502	56.752
Wind.....	3,972	4,119	3,664	3,039	3,161	2,633	2,671	2,433	29,458
Midlake									
Evaporation....	6.815	11.888	8.310	14,369	13.612	6.908	5.753	3.888	68.677
Wind.....	7,794	9,204	8,030	7,731	5,945	7,983	6,306	5,727	69,139

Weather Bureau of the United States Department of Agriculture at Salt Lake City. With the exception of the evaporation data these records extend from 1879 to 1930.

Great Salt Lake

The actual shape and dimensions of Great Salt Lake are matters of no stable mean. The fluctuations in level from season to season and year to year alter the outline of the shore very materially and to a certain extent the dimensions. In general the long axis has a north-west-southeast trend. Its approximate size, according to the U.S. Geological Survey in 1906, is 75 miles long and 35 miles wide. The mean depth in 1929 was about 15 feet. The shape as represented on

the official maps of the Geological Survey shows it at its highest level, which was recorded in 1868. At that time the mean depth was 19 feet and all of the beaches exposed at the present time were submerged by at least 0.5 foot of water. This old shore line is well defined by a terrace ranging from 1 foot or less to 10 feet high. Throughout the ensuing discussions this shore line will be referred to as "the old shore line" or "the shore of 1868."

The deepest part of the lake is found in a trough which runs northwest-southeast between Antelope and Stansbury islands. The records of 1869 give the greatest depth as 49 feet; and with the great recession of 1903 measurements in a similar place showed only 36 feet, a difference of 16 feet, which corresponds to the difference in surface measurements.

The periodic oscillations have been measured over a period of nearly 75 years and on the average show a difference of 2 feet from the wet to the dry period. The level also fluctuates non-periodically chronologically. The level was first measured in 1850. In 1862 a permanent gauge was set up from which monthly readings were taken. Since records have been kept the lake has had one noticeable advance, followed by a recession, and in turn by another less pronounced advance; at present it is sinking again. The following are the important fluctuations:

1850.....	3 feet above the zero on gauge
1868.....	14 feet above the zero on gauge
1874.....	8 feet above the zero on gauge
1877.....	14 feet above the zero on gauge
1903.....	2 feet below the zero on gauge
1923.....	8 feet above the zero on gauge
1931.....	1 foot above the zero on gauge

The zero on the official gauge at Saltair stands at 4194.8 feet above sea level.

CHEMICAL CONSTITUENTS OF THE BRINE.—The waters of the lake have been analyzed repeatedly and the results are shown in table IV (2). The brines vary from 15 to 27.6% according to the level. In comparing the percentage of salts in the water with the fluctuation in level, it is found that there is approximately 1% increase in concentration for every foot decrease in level. This is relative, however,

since a very rapid recession of the lake often causes the salts to be precipitated in great masses of crystals instead of increasing the concentration very much. There are two sources of the salt, concentration of water from streams and contribution from hot mineral springs. The latter are 1-5% salt.

TABLE IV
ANALYSES OF GREAT SALT LAKE WATER (2)

	A	B	C	D	E	F
Cl.	55.99	56.21	56.54	55.23	55.11	53.72
Br.	Trace			Trace		
SO ₄	6.57	6.82	5.97	6.73	6.66	5.95
CO ₃		0.07				
Li.	Trace			Trace		
Na.	33.15	33.45	33.39	34.65	32.97	32.81
K.	1.60	(?)	1.08	2.64	3.13	4.99
Ca.	0.17	0.20	0.42	0.16	0.17	0.31
Mg.	2.52	3.18	2.60	0.57	1.96	2.22
	100.00	100.00	100.00	100.00	100.00	100.00
Percentage salinity.....	14.904	13.790	19.538*	27.720	22.990	17.680

A. ALLEN, O. D., Rept. U.S. Geol. Expl. 40th Par. 2:435. 1877. (Water collected 1869.)

B. SMART, CHARLES, cited in Resources and attractions of the Territory of Utah. (Collected 1877.)

C. TALMAGE, J. E., Science 14:445. 1889. (Collected 1885.)

D. BLUM, W., Reported by TALMAGE in Scot. Geog. Mag. 20:424. 1904. (Collected 1904.)

E. EBAUGH, W. C., and WILLIAMS, K., Chem. Zeitung. 32:409. 1908. (Collected 1908.)

F. MACFARLANE, W., Science 32:568. 1910. (Collected 1910.)

In comparison with other bodies of saline water, Great Salt Lake ranks among the most highly concentrated. The following tabulation shows the percentages of some of the saline lakes of Eurasia (3).

	Percentage salinity
Caspian Sea.	1.294
Sea of Aral.	1.084
Dead Sea.	19.2 to 25.99
Red Lake, Perekop, Crimea.	30.01
Gaukhane Lake, Persia.	25.88

RECENT CONDITIONS.—The period extending from 1929 to 1931 exemplifies rather typical behavior of the lake. During the former year the level was 4-6 feet above the zero on the gauge and within 2 years receded almost to the zero mark, averaging about 1 foot above. It is obvious that bays and inlets fed by fresh-water tributaries have much less salt than the main body of the lake. Table V

TABLE V
PERCENTAGE TOTAL SALTS AND H-ION CONCENTRATION OF BRINES
AT VARIOUS POINTS IN LAKE

LOCALITY	DATE	PERCENT- AGE SALT	pH
Main body:			
Near Saltair.....	June 12, 1929	18.04	8.2
Near Saltair.....	Aug. 30, 1931	20.50	
North Point.....	June 12, 1929	18.06	
Near Jordan delta.....	July 29, 1929	15.71	8.6
West Point.....	July 24, 1929	17.98	
West Farmington.....	Sept. 3, 1931	21.70	
Little Mountain.....	June 29, 1929	18.01	
Bays and inlets:			
East Bay in swamp.....	June 17, 1929	1.03	8.2
East Bay outer limits of swamp..	June 17, 1929	5.86	
East Bay at Jordan delta.....	Sept. 8, 1931	10.60	
Willard Spur, south side.....	July 8, 1929	11.68	
Willard Spur, north side.....	July 8, 1929	8.60	

gives the percentage total salts and H-ion concentration of water taken from representative situations.

The H-ion concentration of the brines is much the same in all parts of the lake. It is perhaps lower than might be expected in such a highly concentrated solution, but the strong buffer action of the weaker acid radicals checks the amount of dissociation. Even fresh waters of the same region have a pH of 8.2, so that there is little or no effect on this value when added to the lake waters.

Flora of Great Salt Lake

GENERAL FEATURES.—The water of Great Salt Lake is clear and transparent. In appearance there is nothing to distinguish it from a body of fresh water. Occasionally masses of algae form local colonies, imparting a brownish tinge to the water, and except in the bays

and inlets no emergent plants grow in it. The high saline constituents render the water toxic and unavailable for the use of most plants. On the lake borders and saline plains trees are absent, succulent herbs and low shrubs predominating. There are a few algae, lichens, and mosses but no liverworts nor pteridophytes. Hackberry and junipers make their closest approach on cliffs and sand dunes, willows occur along the rivers, and poplars have been introduced.

On the basis of salinity the flora of the lake waters may be divided into two general categories, that of the main body of the lake and that of the bays, inlets, and springs.

FLORA OF MAIN BODY OF LAKE.—Algae are the only plants that normally inhabit the main body of the lake where the salt reaches a high concentration. The following were collected:

Myxophyceae:

Aphanothece utahensis Tilden¹

Microcystis packardii Farlow

Oscillatoria tenuis var. *natans* (Kuetz.) Rab.

O. tenuis var. *tergestina* (Kuetz.) Rab.

Chlorophyceae:

Chlamydomonas sp.

Tetraspora lubrica var. *lacunosa* Chauv.

Aphanothece utahensis is the dominant species at the present time. It floats on or near the surface in flaccid, rugose brown masses 4–6 inches in diameter. In local places it sometimes accumulates, imparting a brownish tinge to the water. It is rather evenly distributed in the deeper parts of the lake but is in greatest abundance along the eastern shore, on the eastern side of Stansbury Island, the northern and western sides of Antelope Island, and on the steep shores of the western side of the promontory. *Microcystis packardii* occurs in rather firm gelatinous masses 0.5–1 inch thick, usually spherical but often irregular in shape. The color is most frequently blue-green but brown and pale yellowish tints are common. The species of *Oscillatoria* are much less common and were encountered only occasionally.

¹ The manuals used in the identification of the plants mentioned in this paper were RYDBERG'S Flora of the Rocky Mountains, TIDESTROM'S Flora of Utah and Nevada, COULTER and NELSON'S Manual of Rocky Mountain Botany, LESQUEREUX and JAMES' Manual of North American Mosses, and BARNES and HEALD'S Key to the Genera and Species of Mosses.

All of the collections came from the eastern shore, where it forms thin layers on the muddy bottom in the still and shallow water. *Chlamydomonas* is abundant and fairly evenly distributed in the deeper parts but most common along the shores mentioned in connection with *Aphanothece*. *Tetraspora* floats in the brine along the quiet shores, growing in slimy olive-green masses. It is not common. Several diatoms were collected in the main body and a great many were taken from points where fresh water enters. Identifications were not obtained, but of the former group DAINES (4) says that two of them probably belong to the genera *Navicula* and *Cymbella*. DAINES also isolated in pure cultures five bacteria, four of which were bacilli and one diplococcus. No names are given.

Many other species of algae were taken from the main body of the lake, but the evidence seemed to indicate that they had been washed in from fresh-water situations. Among these are species of *Cladophora*, *Ulothrix*, *Spirogyra*, *Rhizoclonium*, *Enteromorpha plumosa*, and several others that could not be identified. PACKARD (9) reported the first account of the algae in Great Salt Lake in 1879. FARLOW identified the collections, among which he reported *Ulva marginata* Ag. and *Rhizoclonium salinum* Ktz. TILDEN distributed a series of algae from the lake which included *Enteromorpha marginata*, *E. tubulosa*, *Dichothrix utahensis*, and *Chara contraria*. In the present investigation none of these algae was found to be established inhabitants of the main body of the lake, but they grow abundantly in springs and brackish pools along the shore where the salt is greatly reduced in concentration.

FAUNA.—There are three species normally living in the lake water, the brine shrimp, *Artemia gracilis* Verrill, and two salt flies, *Ephydra gracilis* Packard and *E. hians* Say. These animals feed on the algae and are important in connection with the shore deposits.

EFFECTS OF ORGANISMS ON SEDIMENTATION.—The deposition of carbonate is of interest since the origin of this radical was obscure in view of the fact that the ordinary procedure of analysis of the lake water showed no carbonate radical. CAMERON (11) explains the cause of this as follows:

There is sodium carbonate in solution, and normally this would dissociate with the formation of sodium ions, which could be detected with phenolphthalein but the water contains so large amount of salts with sodium ions that the solu-

tion is saturated with respect to this ion, and, carbonates being salts of a weak acid—that is, with a relatively small tendency to dissociate—the dissociation of the sodium carbonate is completely “driven back.” Consequently there is no dissociation in the solution.

If the lake brine is diluted with distilled water, more sodium ions are permitted to enter solution, including those of sodium carbonate. At the same time the ions of the carbonate radical are permitted to go into solution and their presence may be detected with phenolphthalein.

The slightly soluble calcium sulphate occurring in the lake furnishes the calcium ions in the formation of calcium carbonate. This takes place by the forced solution of sodium carbonate resulting from the interaction between sodium chloride and calcium sulphate. The calcium and chlorine ions form calcium chloride, which is very soluble. This increases the solubility of calcium by permitting more calcium sulphate to enter solution. The calcium ions increase beyond their limit of saturation and tend to unite with the carbonate radical. The calcium carbonate is deposited on sand grains forming oolite or upon masses of algae, principally *Aphanothece* and *Microcystis*, forming a tufa-like deposit. In the latter case algae accumulate in shallow water and become cemented down to the increasing bed of tufaceous deposit. This is particularly evident along the shores of the islands and the promontory. Another type of deposit composed of a combination of oolite and tufaceous accumulations is evident in many places. Masses of algae together with the empty nymph shells of the salt fly are washed up on the shore and become incorporated with the grains of oolite. Repeated washing by the waves leaves more and more calcium carbonate in this heterogeneous mass. In this condition the algae become partially disintegrated, forming a mushy mass 4–6 inches deep, the color varying from the naturally bluish green and brown to light tints of pink, yellow, and hyaline. Acres of this gelatinous material are common along the eastern shore. As the lake recedes this material is left exposed on the beach and gradually dries out, resulting in the formation of crusty biscuit-like deposits 1–2 inches thick and 1–3 feet in diameter. These masses are built upon one another and become covered with wind-blown oolite. In time they are transformed into a friable platelike rock resembling

disintegrating sandstone. Older deposits show a thin undulated tufaceous rock, white to pale yellow in color and weathering into small plates. Hardpan and other calcareous deposits have been found in Jordan Valley a few inches to 10 feet deep and 5-10 miles from the present shore of the lake, indicating that this process of rock formation has been taking place over an extended period of time. Along the eastern shore, from the Jordan delta to the mouth of the Weber River, silt together with the vegetable matter becomes incorporated with the algal masses and is turned black by the action of sodium carbonate. As the lake recedes it is left exposed, the surface variegated and apparently solid, but really soft and gelatinous, 6-10 inches deep, and jet black. As the hot sun plays upon it, it puffs up and emits gases of strong sulphurous briny odor. The crusty formations are much the same as those just described, except that they are black with a hoary coat of salt.

While the flora of the lake waters is very limited in number of species of algae, it exerts an important influence on the shore deposits and is directly instrumental in the formation of a specific type of substratum upon which other plants encroach. The ecological significance of the algae becomes two-fold, first, as inhabitants of one of the most highly concentrated natural brines, and, second, as the agents of deposition.

Strand

The term "strand" as used in this paper includes any ground left exposed between the margin of the water and the highest level attained by the lake since records have been kept. This level is well defined by the old shore of 1868. The lateral extent may vary from a few feet near the headlands to nearly 2 miles on the flat beaches. The bars between the mainland and Antelope and Stansbury islands are often exposed. Seasonal variations alter the strand greatly.

The strand deposits may be divided into three groups: sand, oolitic limestone, and mud. The usual conditions show a laminated character of alternating layers of gray, black, and greenish black sediments. The coloring is due to the decay of algae and finely divided vegetable matter brought in by the rivers. Mud and silts occur mainly near the inlets and river deltas. Within a given area the fineness and uniformity of sand and mud may be continuous over a

rather extended range. Where hardpan is in process of genesis a coarser element is introduced.

FLORA.—For the most part the strand is barren. Trees are absent and shrubby plants rare. The pioneer vascular plants are restricted to the extreme margins and occasionally are scattered in isolated groups on the salt flats. The principal types invading the highly concentrated alkali soils may be considered briefly.

The samphires, *Salicornia rubra* and *S. utahensis*, are the first pioneer types of the halosere of Great Salt Lake. They tolerate a higher percentage of alkali in the soil than do any other species. *S. rubra* is an annual plant with opposite branches and minute scale leaves. It is a singular feature that the higher the salt content becomes the shorter and more densely crowded these plants grow. At the very margin of invasion stands 2 inches high are so dense that it would seem impossible for another plant to enter among them. In some places it may be seen to cover a strip of outer strand 30 feet wide, and again it may be absent. In mildly saline soil it reaches a maximum height of 12–14 inches. *S. utahensis* is an endemic plant, perennial, and more robust than the red species. It forms dense caespitose colonies and develops little hummocks of wind-blown material.

Second only to the samphires in toleration of alkali and in its habit of invading is the pickleweed, *Allenrolfea occidentalis*. It is a perennial which becomes shrubby at the base. The stems and leaves are much like those of the samphires but are characterized by alternate branching, and the plant as a whole is much larger and with a different habit of growth. It is common in certain parts of the strand region, invading barren flats, building up little hummocks of wind-blown sand and dust. The annual inkweed, *Suaeda erecta*, is another plant prominent in invasion of the strand. It is less tolerant of alkali and generally follows the samphires and pickleweed. A perennial species, *S. moquinii*, is of more robust habit and often follows the former species. The salt grass, *Distichlis spicata*, is perhaps the most versatile plant in the region. It usually follows the preceding species in the succession, but also enters the strand directly, sending out long rootstocks with the individuals arranged in straight lines.

Less common is *Atriplex hastata*. It is also very versatile though

never attaining any degree of dominance. In soils bearing a moderate amount of alkali and which are dry it is rather small, slender, and silvery gray in color. In very moist or wet soils it becomes tall, branched, and with dark green fleshy leaves. The two types were once regarded as separate species. *Scirpus americanus* and *S. paludosus* are swamp plants tolerant of alkali. They enter the strand at fresh-water inlets, bays, and deltas where the strong alkali is somewhat reduced.

While halophytes become smaller in size the more highly concentrated the salt becomes, the opposite extreme is noted in less saline situations where they reach a maximum size. If, however, the alkali content of the soil becomes less than the optimum, the plants become smaller and more spindling. This situation is seldom observed in nature since competition with other plants soon eliminates them. An example of this is noted in river deltas where the rushes eliminate the samphires.

A point of particular interest is the water relationship of these plants. While the data may tell the percentage salt in soil samples when dry, they tell little regarding the actual conditions while the plants are growing in them. This is due mainly to the varying amounts of water. It has been noted that samphires grow in soils bearing as high as 6.5% salt, calculated from the dry weight of the soil. It is important to note, however, that such soils as harbor samphires have a relatively high water content and that the real feature of significance is the concentration of the soil solution. In the spring the water table is high and the sands and clays are saturated, the concentration is reduced, and germination and growth are initiated. Once started, and the plants having become established, subsequent withdrawal of the water is common. The reaction of the plants differs according to the amount of salt present and the type of soil. Plants persist longer in dry sandy soil than they do in dry clay. The rapidity with which the soil is dried is also a condition bringing about variable plant reactions. In both sandy soil and clay, the slower the drying process the more tenaciously the plants persist, even after the soil becomes very dry and cracked. If the soils are dried out rapidly, however, the plants perish even while there is ample water available.

Several samples of soil were taken from the root region of various typical halophytes and analyses made for water content, total salts, and in some instances for basic constituents. The salts were extracted with excess distilled water, the liquid passed through a porcelain filter, and the filtrate used in standard quantities for analyses. The H-ion concentration was determined with indicator solutions. Typical transects were selected and soil samples taken from the various successional zones. From a number of transects two series of results

TABLE VI

CHEMICAL ANALYSES OF SOILS FROM LITTLE MOUNTAIN AREA; SALTS CALCULATED ON BASIS OF DRY WEIGHT OF SAMPLES. COLLECTED JULY 20, 1929. THE FIRST THREE WERE SAND, THE REMAINDER CLAY

LOCATION	WATER CONTENT	pH	NaCl	Na ₂ CO ₃	NaHCO ₃	Na ₂ SO ₄	TOTAL
Barren salt flat 25 feet from plants	20.84	8.9	17.68	0.339	Trace	4.572	22.59
Two feet from first <i>Salicornia</i> plants.	15.94	8.8	5.89	0.005	0.05	0.852	6.72
<i>Salicornia rubra</i> pioneers.	15.81	8.8	5.30	0.005	0.05	0.401	6.26
<i>Suaeda erecta</i> zone	14.80	9.8	2.60	0.005	0.672	Trace	3.31
<i>Distichlis</i> zone. . .	8.22	8.8	2.21	0.053	0.141	Trace	2.60
<i>Cressa depressa</i> zone.	8.2	9.0	0.651	0.005	0.605	Trace	1.30

are presented here, illustrating the extreme alkali conditions and the average conditions respectively.

LITTLE MOUNTAIN AREA.—The strand at this point shows remarkable plant zonation, although the type of soil changes abruptly. The outer margin toward the lake is black sand and harbors pioneer samphires and a few annual inkweeds. The soil then changes to a heavy clay which bakes hard in late summer. In this part the inkweeds and salt grass are abundant, with scattered *Atriplex hastata*. Farther removed is a zone of *Cressa depressa* and some patches of *Sida hederacea*. *Salicornia rubra* at the margin of invasion is very short and becomes larger as the salt content of the soil decreases. Table VI shows the water, salt content, and pH of the soil.

The high salt content in these zones shows a unique extreme in salt tolerance and was the highest found in the region. KEARNEY,

BRIGGS, and SHANTZ (7) carried on investigations in Tooele Valley and report the average salt content of the *Salicornia* zone at 2.5%. HALKET (6) demonstrated that some species of *Salicornia* tolerate salt up to 5% in artificial cultures. The strand at this point has a high water table and the soils are saturated until summer sets in and then they begin to dry out slowly. The abundant water serves to dilute the strong salt and may be the main factor permitting the plants to survive in this highly saline habitat.

EASTERN SECTION.—The relatively flat beaches are of fine gray sand for the most part, with local areas of coarse calcareous material and decaying algal masses. Invading plants form an irregular line toward the lake side and seem to be limited only by high salt content of the soil and to a less extent by the mucky algal masses. The samphires are the most frequent plants to enter the barren areas, although the annual inkweed and salt grass lead the invasion in many places. Several transects of soil samples were taken through typical situations and the water and alkali conditions studied. The results bear out the conclusion that the critical period determining the vegetation is early spring when the water table is high and the strong soil solutes are more dilute than later in the season. The optimum salt concentration for the samphires ranges between 2.5 and 3.5% during the early spring, but conditions become variable as the water withdraws. Table VII shows the analyses of a typical area taken in July after the water table had gone down considerably.

The H-ion concentration of the soils throughout the region seems to show little or no relationship to the types of vegetation and in no way was it possible to use this as a factor determining the species or vegetation.

FLORISTICS.—The floristic features may be divided according to the predominating soil and topographic features, and in addition, the climatic and surface water relations. The eastern section receives about 10 inches more rainfall than the northern and western portions.

The eastern section, extending from Little Mountain to the Jordan delta, presents a strand of diverse situations. Numerous strand swamps, inlets, and springs introduce contrasting plant communities, while the greatest extent of the strand shows the usual pioneers al-

ready cited. The soil is of the black sand type previously mentioned. A bluff or terrace has been cut in the old delta deposits of the Weber River so that there is an abrupt break in the vegetation. This topographic feature narrows the successional zones so that there are no gradual transitional zones between the pioneer and intermediate types. To the north and south the terrace dwindles and the extremities show the gradual entrance of species from the saline plains.

The section extending from the Jordan delta to the southern tip of the lake is likewise one of diversity, with strand swamps, springs, calcareous dunes, and rocky headlands. The flora in this section

TABLE VII

ANALYSES OF SOIL SAMPLES FROM SALTAIR AREA; SALTS CALCULATED TO DRY WEIGHT OF SOIL. COLLECTED JULY 12, 1929

LOCATION	WATER CONTENT	pH	NaCl	Na ₂ CO ₃	NaHCO ₃	Na ₂ SO ₄	TOTAL
Invading <i>Salicornia rubra</i>	14.10	8.4	4.08	0.052	0.022	0.853	4.99
<i>Suaeda erecta</i> zone surface soil....	9.14	8.8	2.68	0.084	Trace	1.421	4.80
Same, 2 feet deep.	18.20	8.4	1.51	0.084	Trace	0.433	2.01
<i>Distichlis</i> zone surface soil....	3.59	8.6	0.07	0.057	Trace	0.497	0.62
Same, 2 feet deep.	10.81	8.6	0.06	0.10	0.012	0.384	0.54

sums up suitably most of the features common to the entire eastern side of the lake. The sand is very fine along the water's edge but toward the outer margin it becomes coarser, with calcareous material predominating. The invading species grow mainly in this coarser soil but a few may be noted in isolated colonies on the sand flats.

Generally there are several well defined zones. The pioneer types are more or less constant but the zones further removed become more and more diverse. This becomes evident in passing from one situation to another; the same pioneers persist but those following change or form different combinations with other species. Notable among the sandy beach elements are *Spartina*, *Abronia*, *Eriocoma*, and *Sphaerostigma*. The succession on the Saltair and Garfield beaches shows the following zones:

Zone 1. *Salicornia rubra* A. Nels.

S. utahensis Tidest.

- Zone 2. *Suaeda erecta* (Wats.) A. Nels.
Zone 3. *Distichlis spicata* (L.) Greene
Zone 4. *Spartina gracilis* Trin.
 Eriocoma cuspidata Nutt.
 Puccinellia nuttalliana (Schultes) Hitchc.
 Bromus tectorum L.
 Abronia salsa Rydb.
 Sphaerostigma utahensis Small
Zone 5. *Sporobolus asperifolius* (Nees. & Mey.) Thurb.
 Distichlis spicata (L.) Greene
 Atriplex hastata L.

Zones 4 and 5 are the most variable. Frequently *Suaeda moquinii* is present. The following plants are also common entrants:

- Sporobolus airoides* Torr.
 S. cryptandrus (Torr.) Gray
 Poa nevadensis Vasey
 Bromus tectorum L.
 Sitanion hystrix (Nutt.) J. G. Smith
 Atriplex hastata L.
 A. confertifolia (Torr.) Wats.
 A. rosea L.
 Pachylophus marginatus (Nutt.) Rydb.
 Gutierrezia microcephala Gray
 Chrysothamnus pulcherrimus Greene
 Iva axillaris Pursh

Most of these plants are common inhabitants of the calcareous dunes forming the outer limits of the strand.

BURMISTER-DELLE CREEK SECTION.—This section is at the southern extremity of the lake and presents one of the broadest stretches of exposed beaches. At times when the lake is low the Stansbury Bar is exposed throughout the year, and only during the spring months are the extensive flats saturated with water. This is mainly precipitation and ground water. The general aspect presents a barren salt flat, white on the surface but with the underlying strata yellowish and with gray clays laminated with darker streaks. It retains the water until late summer when the outer margins become dry and cracked.

The topography north of Burmister and on the Stansbury Bar is interesting, as the salt flats are interrupted by a number of small island-like raised areas which stand 4-6 feet above the general level. They are composed of clay loam and harbor a flora of greasewood and shadscale which extends to the very margin and produces a marked contrast with the barren salt flats. These islands vary in size up to several hundred yards across.

For the most part there is no vegetation on the flats. Toward the mainland a few outposts of *Allenrolfea* and occasionally *Salicornia* appear in scattered colonies. *Allenrolfea* is almost the exclusive pioneer plant in many places. It builds the little hummocks described previously, often giving the surface a spotted appearance. The salt grass is generally the next plant to enter, with its characteristic habit of sending out long root stocks. A variety of plants may enter next, depending upon the locality and the conditions. The eastern portion finds a rich development of *Salicornia utahensis*, especially along moist playas where springs occur. Most of the portions surrounding the islands have species of *Suaeda* entering next, while toward the western portion little playa meadows are common. These may be occupied almost exclusively by salt grass or a mixed flora of salt grass, *Sporobolus airoides*, *S. cryptandrus*, *Puccinellia nuttalliana*, *Triglochin maritima*, and *Cressa erecta*.

The succession is various, often narrow in its zonation, and difficult to follow. The following arrangement indicates the usual order of approach:

- Zone 1. *Allenrolfea occidentalis* (Wats.) Kuntze
 Suaeda erecta (Wats.) A. Nels.
 S. moquinii (Torr.) A. Nels.
- Zone 3. *Distichlis spicata* (L.) Greene
- Zone 4. *Suaeda diffusa* Wats.
 Atriplex confertifolia (Torr.) Wats.
 Sarcobatus vermiculatus (Hook.) Torr.

STANSBURY ISLAND.—The strand of Stansbury Island is continuous with that of the mainland at the present time. On either side at the south end it is very broad but it becomes gradually narrowed toward the middle of the island. On the east side and at the north it is

narrow, and often steep and rocky. In general the flora is much the same as that already described. The main contrasting feature is the presence of two parallel beach bars along the eastern shore near the middle. They are composed of a coarse, clean white calcareous sand arising from a shore of friable hardpan in process of genesis. The vegetation is in distinct zones with a number of new entrants. Notable among the latter are *Mentzelia*, *Cleome*, and *Amelanchier mormonica*. The steep slopes immediately behind these bars make it possible for a number of non-halophytic plants to make a rather close approach to the lake. The following zones may be recognized:

- Zone 1. *Salicornia rubra* A. Nels.
 S. utahensis Tidest.
- Zone 2. *Suaeda erecta* (Wats.) A. Nels.
 Allenrolfea occidentalis (Wats.) Kuntze
- Zone 3. *Atriplex argentea* Nutt.
 Amaranthus graecizans L.
 Salsola pestifer A. Nels.
 Mentzelia laevicaulis (Dougl.) T. & G.
 Sphaerostigma utahensis Small
- Zone 4. *Distichlis spicata* (L.) Greene
 Bromus tectorum L.
 Cleome serrulata Pursh
 Amelanchier mormonica C.K. Schneider

In this vicinity a number of dead stumps of *Sarcobatus* and *Tetradymia spinosa* were observed, suggesting that the succession at one time reached a somewhat advanced stage before the rise of the lake killed them. In some places there is a well defined line of empty shells of the salt fly larvae, indicating the upper limits of the storm waves.

WESTERN AND NORTHERN SECTIONS.—The broadest expanse of barren strand is to be found in the western and northern portions of the lake. In many places the water's edge is nearly 2 miles from the old shore line. The white salt flats are interrupted only by drift wood and occasional hummocks of *Allenrolfea*. The latter were found nearly a mile out on the flats, with no intervening vegetation. In the major features the plants merely accentuate the richness and

halophytic character of the vegetation. The species show no further features beyond those already considered, and only local variations distinguish the region from the successional zones of the eastern and southern sections. The topography presents a very irregular line marking the old shore; long narrow terraces extend toward the lake with deep sinuous bays separating them. In the latter, salt grass meadows are common while pure strands of the various species may be found. Rich growths of *Suaeda*, *Salicornia*, *Allenrolfea*, and the several species of *Sporobolus* show these plants at their best.

The main influences of climate lie in light, heat, and evaporation. The bright glaring sunlight is perhaps more apparent than real and does not compare with that of high mountain tops, but the vegetation receives a maximum amount for valley regions. The surface temperature of the soil often reaches 36° to 38° C. The evaporation is high, and although the water supply is ample during the spring and early summer months, the gradual withdrawal of the groundwater, together with the increasing concentration of the soil solution, renders the strand one of the most unique of ecological situations.

INLETS, STRAND SWAMPS, AND SPRINGS

Fresh-water inlets and springs are common along the eastern side of the lake. At their points of entry into the lake the concentration of the salt is greatly reduced and a number of contrasting situations are to be found.

BEAR RIVER BAY.—The northern and eastern portions of Bear River Bay are bordered by broad mud flats, while the western border is more abrupt with several rocky points and numerous mineral springs on the strand. The Southern Pacific Railroad trestle extends across the mouth of the bay and forms a barrier which tends to retain the fresh-water in the bay and exclude the strong brines from the main body of the lake. The reduction in amount of salt from the trestle northward is as follows:

Little Mountain just north of the	
Southern Pacific trestle.....	18.01%
Willard Spur, south side.....	11.68%
Willard Spur, north side.....	8.60%

WILLARD SPUR AREA.—The Willard Spur is a shallow arm of Bear River Bay which extends eastward. The mud flats and substratum of the shallow water are undulating, with numerous slight depressions which retain little pools as the water recedes. Flaky accumulations of decaying vegetable matter lie half suspended in the water, while countless small crustaceans (*Cypris* sp.) crowd the margins and are left stranded as the water recedes. In the shallow pools a form of *Cladophora fraeta* occurs, often becoming very abundant. *Potamogeton pectinatus* and *Ruppia maritima* are other

TABLE VIII

PERCENTAGE MOISTURE, PH, AND PERCENTAGE TOTAL SALTS OF SOILS FROM
WILLARD SPUR (SALTS ON BASIS OF DRY WEIGHT OF SAMPLES).
COLLECTED JUNE 29, 1929

LOCATION	WATER CONTENT	PH	TOTAL SALTS
Clay silt from bottom of shallow pool.....	31.6	8.4	2.01
Clay flat, 20 feet from water.....	22.0	8.4	1.83
Dry clay flat, <i>Salicornia</i> wilting.....	10.2	8.6	1.76
Clay cracked and dry, <i>Salicornia</i> dead.....	8.0	8.8	1.31
Clay loam bordering cultivated fields.....	21.7	8.6	1.35
Same with <i>Suaeda erecta</i>	14.0	8.6	0.91

members of the aquatic society. *Salicornia rubra* germinates and reaches a robust size in water 2–3 inches deep. On the mud flats it is abundant as long as the water remains, but as summer passes desiccation becomes more and more severe until there is no longer sufficient water to maintain vegetation. The plants follow the water as it recedes. A transect of soil samples was taken from the water's margin for a mile back to the old shore line. Table VIII shows the analyses.

Lack of circulation of the water in the shallow portions of bays permits the accumulation of heat. Thus on July 29, with the air temperature at 32° C., the water of the main body of the lake was 19° C. at midday while the shallow water of Willard Spur was 31° C.

The mud flats are inhabited almost exclusively by *Salicornia rubra*. Following are a few scattered *Allenrolfea*, then an irregular zone of *Atriplex hastata*, and next an irregular zone of *A. truncata*. Grasses

enter next with numerous annuals and a few shrubs, forming a mixed association as follows:

Hordeum jubatum L.
H. gussonianum Parl.
Polygonum aviculare L.
Sarcobatus vermiculatus (Hook.) Torr.
Lepidium perfoliatum L.
L. pubicarpum A. Nels.
Sisymbrium altissimum L.
Allocarya nitens Greene
Matricaria suaveolens (Pursh) Buchen.
Grindelia squarrosa (Pursh) Dunal
Helianthus annuus L.

In seepage areas the following appear:

Puccinellia nuttalliana (Schultes) Hitchc.
Hordeum jubatum L.
Atriplex hastata L.
Spergularia salina Presl.
Ranunculus eremogenes Greene
Halerpestes cymbalaria (Pursh) Greene

THE PROMONTORY.—The strand on the east side of the Promontory is narrow, the mountains rising rather abruptly from the shore. A few steep headlands are conjunctive with the strand and the beach is strewn with rocks, in some places forming a shingle beach. The residual rocks are near the surface and numerous springs arise through the crevices, some bearing minerals and flammable gases.

The following algae were recorded:

Oscillatoria animalis Ag.
O. spp.
Enteromorpha intestinalis L.
Vaucheria sp.
Spirogyra sp.

The steepness of the strand in many places makes the zones of transition between the strongly saline soils and fresh soils very narrow, and consequently the successional zones are much contracted

and overlapped. The following zones are generalized from several situations:

- Zone 1. *Salicornia rubra* A. Nels.
- Zone 2. *Polypogon monspeliensis* (L.) Desv.
Distichlis spicata (L.) Greene
- Zone 3. *Hordeum jubatum* L.
Halerpestes cymbalaria (Pursh) Greene
- Zone 4. *Scirpus americanus* Pers.
S. paludosus A. Nels.
S. olneyi Gray

Meadows and muddy banks show a variety of plants and three main groups may be identified according to the degree of halophytism. Where the salt is strong the following occur:

- Puccinellia nuttalliana* (Schultes) Hitchc.
- Distichlis spicata* (L.) Greene
- Polypogon monspeliensis* (L.) Desv.
- Hordeum jubatum* L.
- H. gussonianum* Parl.
- Sitanion* sp.
- Juncus balticus* Willd.
- Rumex crispus* L.
- Suaeda erecta* (Wats.) A. Nels.
- Atriplex rosea* L.
- A. argentea* Nutt.
- A. hastata* L.

Other situations show many composites:

- Triglochin maritima* L.
- Sporobolus airoides* Torr.
- Spergularia salina* Presl.
- Melilotus alba* Desv.
- Achillea millefolium* L.
- Aplopappus lanceolatus* (Hook.) T. & G.
- Agoseris* spp.
- Helianthus annuus* L.
- Iva axillaris* Pursh
- Leontodon taraxacum* L.

Some seepage areas have leached much of the alkali from the soil and present the following:

Lemna minor L.
Carex sp.
Berula erecta (Huds.) Coville
Glaux maritima L.
Asclepias speciosa Torr.
Castilleja exilis A. Nels.
Sonchus asper (L.) Hill

On the upper dry side of some of these mildly saline situations *Cleome serrulata* grows in dense masses; *Euphorbia glyptosperma*, *Polygonum aviculare*, *Artemisia tridentata*, and several species of *Chrysothamnus* are also found.

EASTERN SECTION.—From Little Mountain to East Bay there are numerous inlets and strand swamps. They are much alike in character and composition with a few variations according to the situation. *Cladophora* and *Spirogyra* are common; *Scirpus americanus* and *S. paludosus* usually appear in the inlets; the grasses *Puccinellia*, *Hordeum jubatum*, *Polypogon*, and *Distichlis* are common. Near the village of Hooper is a shallow strand swamp harboring a low and rather uniform vegetation. It is characterized by many small water channels with tussocks of plants and decaying accumulations. The algae are abundant; *Potamogeton pectinatus* and *Ruppia maritima* are submerged types and *Lemna minor* floats on the surface. The emergent society is composed of:

Sagittaria cuneata Scheld.
Scirpus spp.
Eleocharis palustris (L.) H. & B.
E. acicularis (L.) R. & S.
Cicuta occidentalis Greene
Berula erecta (Huds.) Coville

On the borders and on heaps of decaying vegetable matter the following enter:

Polypogon monspeliensis (L.) Desv.
Puccinellia nuttalliana (Schultes) Hitchc.
Sporobolus airoides Torr.

Atriplex hastata L. •

Trifolium pratense L.

Epilobium adenocaulon Hausskn.

The swamp community in East Bay is one of contrasts. The outer portion toward the lake is much more saline than the portion toward the shore. The salt content of the water was found to be 5.86 and 1.03% respectively. The algae are abundant, appearing at a distance like a green meadow. *Salicornia rubra* is prominent and grows in water 2 or 3 inches deep. *Scirpus* spp. are present while *Typha* enters as a new member. The associated species include those already mentioned and also *Scirpus lacustris*, *Ranunculus eremogenes*, *Halerpestes cymbalaria*, and *Radicula nasturtium-aquaticum*.

Numerous other strand situations occur in other sections surrounding the lake, but present only slight variations of those cited. Black Rock, Lake Point, Delle Creek, and near the Salt Wells are other localities where fresh water enters.

River deltas

As physiographic units the deltas of the three largest rivers tributary to the lake are much the same in the character of the sediments deposited and in their vegetation. All are composed of heavy dark brown or gray clays of varying alkali content. The rivers are muddy. At present the conditions are much altered by the interference of duck clubs, dikes having been built around the distal extremities of the Jordan delta and across the north limb of the Bear River delta. Headgates in the dikes are closed during part of the year and the water backed up in the delta, extending the marsh land. Headgates have also been built at the point where the rivers enter the deltas and the flow of water through the various channels regulated. In the Jordan delta 3600 acres are submerged to a depth of 3 feet. Every spring the headgates are opened and the deltas drained. Strong winds often blow the lake brine back into the deltas, killing numerous fish and other animals besides increasing the alkali content of the soils.

The soil and water conditions when the Jordan delta was drained are shown in table IX.

The vegetation is augmented by introduction of seeds and cuttings of plants beneficial to ducks and other birds. Among the plants introduced are:

Sparganium eurycarpum Engelm.
 Potamogeton pectinatus L.
 Ruppia maritima L.
 Scirpus americanus Pers.
 S. validus Vahl.
 S. lacustris L.
 S. paludosus A. Nels.
 Puccinellia nuttalliana (Schultes) Hitchc.

The seeds of these plants are relished very much by birds, and extensive fields of *Scirpus americanus* are cultivated. When the

TABLE IX

CHEMICAL ANALYSIS OF SOILS FROM JORDAN DELTA; SALTS CALCULATED IN TERMS OF DRY WEIGHT OF SAMPLES. COLLECTED JULY 29, 1929

LOCATION	WATER CONTENT	PH	NaCl	Na ₂ CO ₃	NaHCO ₃	Na ₂ SO ₄	TOTAL SALTS
Salicornia	26.8	8.6	0.323	0.084	Trace	1.56	2.08
Scirpus spp.	22.8	8.6	0.389	0.084	"	0.99	1.40
Typha and Spar- ganium	25.8	8.6	0.328	0.082	"	0.81	1.27

deltas are drained in the spring the mud flats dry out and by August the fields are mowed. The following societies constitute the dominant flora:

Free-floating:

Spirogyra sp.
 Cladophora fraeta forma

Anchored submerged:

Potamogeton pectinatus L.
 Ruppia maritima L.

Emergent types:

Scirpus americanus Pers.
 S. paludosus A. Nels.

S. lacustris L.
S. validus Vahl.
S. olneyi Gray

Emergent types restricted to muddy banks:

Sparganium eurycarpum Engelm.
Typha latifolia L.
T. angustifolia L.
Phragmites communis Trin.
Puccinellia nuttalliana (Schultes) Hitchc.
Distichlis spicata (L.) Greene
Rumex crispus L.
R. britannica L.
Salicornia rubra A. Nels.
Sonchus asper (L.) Hill

Types restricted to banks:

Triglochin maritima L.
Spartina gracilis Trin.
Hordeum jubatum L.
Polypogon monspeliensis (L.) Desv.
Atriplex hastata L.
A. rosea L.
Suaeda erecta (Wats.) A. Nels.
S. moquinii (Torr.) A. Nels.
Amaranthus retroflexus L.
Sida hederacea (Dougl.) Torr.
Asclepias speciosa Torr.
A. mexicana Cav.
Apocynum cannabinum L.
Iva axillaris Pursh
I. xanthifolia Nutt.
Grindelia squarrosa (Pursh) Dunal
Xanthium pennsylvanicum Wallr.
Helenium autumnale L.
Lactuca scariola L.
L. integrata (Gren. & Godr.) A. Nels.

Halerpestes cymbalaria becomes prominent along the margins after the delta is drained, while *Salicornia* invades the barren flats.

Playas and alkaline plains

A large part of the valleys surrounding Great Salt Lake have soils that are strongly alkaline. Successively these valleys have been the bed of the lake and the strands, and at present they have been reclaimed to a large extent by vegetation. The general physiographic features show a plain interrupted by playas, sloughs, drainage canals, and streams. Permanent streams traverse the region mainly on the eastern side, and it is on this side that much of the land has been turned to agricultural uses wherever drainage has been possible.

SOIL, ALKALI, AND GROUND-WATER.—Coarse grained oolitic sands and hardpan derivatives are common along the lake borders. The surface soil of the plains is dominantly Jordan loam with a subsoil of loam or clay. In the depressions the surface soil is usually Jordan clay with a subsoil of the same character. Sand is not frequent and hardpan is a subsoil type.

In a given column of soil the alkali content is often governed by the amount of water in it. In regions where the water table is deep the precipitation water tends to carry the salt deeper into the soil, leaving the surface layers with relatively small amounts. On the other hand, where the water table is close to the surface the water is drawn to the surface, carrying with it the soluble salts which are deposited in the upper layers of soil. A number of surveys of the soil and water conditions (1, 5, 7, 10, 11) furnish data which show that the percentage of alkali in the soil increases roughly in proportion to the shallowness of the water table, as follows:

Depth of water table below surface	Percentage of alkali
3 feet or less.	3% or more
6 feet.	1-3%
10 feet.	0.25-1%

Specific data correlated with the vegetation will be given in the following sections.

PLAYAS

Playas are numerous and occur in nearly all parts of the valleys. Generally they are alike in soil, alkali, and water relations, few showing marked differences from the general conditions exhibited by the majority. Floristically they are strikingly similar although local variations are common. A distinction must be drawn for a correct understanding of this presentation. For convenience they may be considered in three groups: (1) the young undeveloped situations usually presenting a barren flat with a pioneer vegetation encroach-

TABLE X
GENERALIZED SOIL TRANSECT OF PIONEER PLAYA SHOWING PER-
CENTAGE ALKALI CALCULATED IN TERMS OF DRY WEIGHT OF
SOIL. WATER TABLE THREE FEET OR LESS IN EACH INSTANCE.
JUNE 25, 1929

No.	TYPE OF PLANT	SURFACE	2 FEET	3 FEET
41	Barren area	7.06	6.55	10.91
42	“ “	3.55	6.60	5.30
43	“ “	3.02	5.05	5.00
54	Salicornia rubra	2.42		
44	“ “	2.00	4.15	4.11
35	Allenrolfea	0.98	1.00	1.03
36	“	1.54	1.61	1.60
45	Suaeda erecta	1.47	2.03	1.98
46	“ “	1.48	1.68	1.70

ing from the margins; (2) the intermediate situations where the entire playa has been invaded; (3) those which have been reclaimed by a halophytic flora. Most playas are alike in the early stages but diverse in the intermediate stages. None was observed in the mature stage.

PIONEER STAGES.—Pioneer types of the playas are much the same as those of the strand. The main difference lies in the habit and distribution of the plants. *Salicornia rubra* and *S. utahensis* are the most frequent species invading the barren playas, although *Allenrolfea occidentalis*, *Suaeda erecta*, *S. moquinii*, *S. occidentalis*, and *Distichlis spicata* are not uncommon in this capacity also. There seems to be little reaction of the plants to the type of soil in which they grow. The great determinative factor is a certain amount of

water; the great unifying factor is a certain amount of alkali. The amount of salt present in dry soils varies greatly, ranging from 0.05 to 10.0%. The concentration of soil solute depends upon the amount

TABLE XI
DOMINANT HALOPHYTES AND THEIR PH RELATIONS

No.	TYPE OF PLANT	LOCALITY	TYPE OF SOIL	pH
109	Barren	Jordan Valley	Jordan clay	8.0
112		" "	" "	8.6
138		Weber Valley	" "	8.9
139	Salicornia	Weber Valley	Salt Lake sand	9.0
108		Jordan Valley	Jordan loam	8.6
115		" "	" "	8.7
121		" "	Salt Lake sand	8.4
169		Tooele Valley	Hardpan	8.4
170		" "	Jordan clay	8.5
110	Suaeda erecta	Jordan Valley	Jordan clay	8.6
125		" "	Salt Lake sand	8.4
186		" "	Jordan loam	8.4
151		Weber Valley	Salt Lake sand	9.8
140		" "	" " "	9.8
125	Suaeda moquinii	Jordan Valley	Salt Lake sand	8.4
132		" "	Jordan loam	8.6
152		Weber Valley	Salt Lake sand	9.8
106	Allenrolfea	Jordan Valley	Jordan clay	9.0
110		" "	" "	8.6
111		" "	" "	8.2
187		" "	Jordan loam	8.5
189		" "	" "	8.6
145		Weber Valley	Jordan clay	8.6
146		" "	" "	9.0
159		Tooele Valley	" "	8.8
162		" "	" "	9.1
105	Distichlis	Jordan Valley	Jordan clay	8.8
181		" "	Salt Lake sand	9.1
185		" "	Jordan loam	8.4
193		" "	" "	8.6
200		Jordan delta	Jordan clay	8.6
153		Weber Valley	Salt Lake sand	9.6

of water in the soil, which is an extremely variable factor during the growing season. Soils of low percentage of salts and a small amount of water become as drastic as soils with high salt percentage and a large amount of water. Thus the strand has high percentage of salt and the water table is slow to withdraw, and *Salicornia* thrives in

these conditions. On the other hand the playas lose water faster and the soil solutes concentrate faster, so that the plants can persist only in soils showing approximately 2% salt in terms of dry weight. The values obtained from soil analyses of typical playa successions show the series to be very similar. The *Salicornia* belt averages about 2% salt, *Suaeda erecta* about 1.5%, and *Allenrolfea* about 1%. None of these plants was found in extremely strong salt as was the case on the strand. Table X represents the average conditions found in typical playas.

No correlation could be made between the H-ion concentration of the soil and the type of plants growing in it, nor could any correlation be made between the H-ion values and the types of soils and their water content. With such a range of values little can be interpreted other than the fact that these plants will tolerate a rather wide range. Table XI gives specific data in this connection.

INTERMEDIATE STAGES.—In the following discussions the term "intermediate stage" covers a number of diverse situations. In most playas there is generally an increase in the amount of alkali from the borders toward the center, so that the succession of plants follows as fast as the alkali is reduced. In some playas this is apparently not the case, however, but the alkali content is more or less uniform in all parts. In the first instance the vegetation is mixed and in the latter it is more or less homogeneous.

MIXED PLAYA SUCCESSION.—Following the pioneer species are two rather well defined belts of plants, the first group dominated by the Chenopodiaceae and the second by a number of small annuals. In group one the first three species named make up the vernal aspect and the remainder the summer aspect.

Triglochin maritima L.

Bromus tectorum L.

Puccinellia nuttalliana (Schultes) Hitchc.

Atriplex argentea L.

A. hastata L.

Suaeda intermedia Wats.

S. moquinii (Torr.) A. Nels.

Salsola pestifer A. Nels.

Bassia hyssopifolia (Parl.) Kuntze
Sesuvium sessile Pers.

The second group following these plants includes:

Deschampsia danthonioides Monro.
Myosurus apetalus Gay
Lepidium perfoliatum L.
L. dictyotum Gray
Hutchinsia procumbens (L.) Desv.
Arabis spp.
Allocarya nitens Greene
Plantago elongata Pursh
P. purshii Roem. & Schult.
Psilocarphus globiferus Nutt.

Of this second group all are annuals except *Deschampsia danthonioides*, and compose the vernal aspect. The alkali content of the soil of the first belt averages about 1.0% and of the second belt from 0.6 to 0.8%.

The terraces bordering the playas harbor a greasewood and shade-scale association and certain elements of this association are creeping out on the playas. Among the plants noted are:

Atriplex confertifolia (Torr.) Wats.
A. nuttallii Wats.
Kochia vestita (Wats.) A. Nels.
Eurotia lanata (Pursh) Moq.
Sarcobatus vermiculatus (Hook.) Torr.
Tetradymia spinosa Gray

RECLAIMED HOMOGENEOUS PLAYAS.—It is assumed that a playa is reclaimed when it is occupied by plants in such numbers as to create sharp competition among them. In many instances a single species may invade a new area so as completely to occupy the ground and preclude the entrance of any other species except an occasional plant here and there. Uniform conditions partly explain this situation, but the more apparent reason is that the one species got there first in great numbers. Where playas are reclaimed by a single species there is usually a robust growth showing the plant at its optimum.

Soil samples were taken from selected communities of this type and the salt contents are shown in table XII.

SALICORNIA FLATS.—There are a few instances where a playa becomes completely invaded by dense growths of *Salicornia*. Usually in such areas the salt is rather strong but does not exceed the optimum of about 2.5 to 3%. The water table is usually high during a greater part of the year. One large community of this kind occurs in Hansel Valley.

TABLE XII

PERCENTAGE OF ALKALI IN SOILS OF RECLAIMED PLAYAS CALCULATED IN TERMS OF DRY WEIGHT. WATER TABLE 3 FEET OR LESS FROM SURFACE IN EACH INSTANCE. JUNE 28, 1929

No.	LOCALITY	SURFACE	2 FEET	3 FEET
32	Allenrolfea flat	1.41	1.12	1.16
35	" "	0.98	1.00	1.03
36	" "	1.54	1.61	1.60
34	Suaeda moquinii flat	0.81	0.80	0.74
25	" " "	1.03	0.95	0.99
31	Distichlis meadow	0.96	1.01	1.12
33	" "	0.96	1.45	1.22
34	" "	0.82	0.84	1.00
29	Sporobolus field	0.55	0.89	1.07
30	" "	0.54	0.83	0.97

ALLENROLFEA FLATS.—This plant prefers a more open distribution, and while it becomes dense several other species are scattered throughout the flat. The alkali optimum is from 1.0 to 1.4%. Hansel and Curlew valleys show numerous communities of this type. The commonest species occurring with it are *Salicornia rubra* and *Suaeda erecta*. *Distichlis* also occurs with it where the water table is high. Generally the pickleweed tends to stay more or less by itself.

SALT GRASS MEADOWS.—It is not unusual to see continuous areas of dense salt grass. Of all the halophytic species in this region it is the most cosmopolitan. It occurs in nearly every kind of situation that furnishes a fair supply of water during the spring and early summer months. As a competitor in successions it tends to eliminate most plants, and once established it is slow to yield to other vegetation. Its success lies mainly in its habit of sending out long root stocks with numerous individuals disposed in straight lines. Its range of alkali tolerance is perhaps wider than that of any other

species. It grows in mildly saline soil and will also enter the most drastic soils following the samphires. With its relatively high competitive power it will dominate the ground wherever it can.

Where salt grass is dominant there are few and usually scattered associates. The most frequent ones are *Allenrolfea*, *Atriplex*, and *Suaeda*. The following is a complete list:

- Atriplex hastata* L.
- A. argentea* L.
- Suaeda intermedia* Wats.
- S. occidentalis* (Wats.) A. Nels.
- Sida hederacea* (Dougl.) Torr.
- Glaux maritima* L.
- Cressa erecta* Rydb.
- C. depressa* Good.
- Adenostegia ramosa* (Nutt.) Greene

The seasonal aspect is almost entirely summer and fall.

SPOROBOLUS FIELDS.—*S. airoides* grows in coarse caespitose bunches where the alkali content of the soil is about 0.5%. It is noted as a ground-water feeder. Associated with it are *S. cryptandrus*, *S. asperifolius*, and *Bromus tectorum*, besides a great many other less common plants. While its sociability is marked its habit of growth and soil relations are such that it does not afford a great deal of competition. The coverage is rather uniform where it is dominant, presenting dense tufts of feathery character but usually rather widely disposed. Interspersed is a wide variety of species. Of all the reclaimed playa situations the *Sporobolus* fields are the most variable and represent the commonest type preceding the grease-wood-shadscale association.

With the exception of the species of *Sporobolus* and *Sitanion*, most of the vernal flora is composed of annuals included in the Graminaeae and Cruciferae. The composition is as follows:

Dominant species:

- Sporobolus airoides* Torr.
- S. cryptandrus* (Torr.) Gray
- S. asperifolius* (Nees. & Mey.) Thurb.
- Bromus tectorum* L.

Less common species:

Bromus hordeaceus L.
Hordeum gussonianum Parl.
Sitanion hystrix (Nutt.) J. G. Smith
Lepidium perfoliatum L.
L. dictyotum Gray
Malcolmia africana (Willd.) A. Br.
Draba nemorosa L.
D. micrantha Nutt.
Sophia pinnata (Walt.) Brit.
S. sophia L.
Sisymbrium altissimum L.
Camelina microcarpa Andrz.

In certain advanced stages in the reclamation of playas the vernal flora is followed by summer and autumn aspects represented almost exclusively by the Chenopodiaceae and Compositae. Notable among these are species of *Atriplex* and *Chrysothamnus*. The following is a more complete list, all of which are perennials:

Atriplex confertifolia (Torr.) Wats.
A. truncata (Torr.) Gray
A. nuttallii Wats.
Eurotia lanata (Pursh) Moq.
Kochia americana Wats.
K. vestita (Wats.) A. Nels.
Sarcobatus vermiculatus (Hook.) Torr.
Suaeda depressa (Pursh) Wats.
S. intermedia Wats.
S. moquinii (Torr.) A. Nels.
Gutierrezia microcephala Gray
Chrysothamnus nauseosus (Pall.) Brit.
C. pulcherrimus Greene
C. pinifolius Greene
C. viscidiflorus tortifolius (Gray) Greene
Viguiera ciliata (Robins. & Greene) Blake
Artemisia spinescens Eat.
A. tridentata Nutt.

GREAT AMERICAN DESERT.—This is a large playa 50 by 100 miles in extent and was the last extensive basin vacated by Great Salt Lake in its decline. The saline constituents permeate the soils to considerable depth and in many places the salt is relatively pure. The surface for the greatest extent is white with a crust of salt covering the yellowish and gray clays. The broad expanse is subject to wind erosion and the removal of vast amounts of salt during storms. While a large part of the desert is barren and without even an occasional plant to interrupt the monotony of the white surface, the area as a whole is far from being entirely barren. The pickleweed has become established in widely scattered hummocks along the broad border and in certain places in mid-desert. The samphires are scanty. Toward the surrounding hills the pickleweed increases in density, scanty growths of salt grass appear, and finally the inkweeds enter. The distribution of these plants is spotty and irregular, some places showing dense stands, but the greatest extent shows a poor, dwarfed, and wind-swept vegetation. The dual effects of climate and alkali render this area one of the most forbidding deserts on this continent, and the vegetation leading to its reclamation must meet a double problem.

Alkaline plains

The plains differ from the playas in being higher areas that do not accumulate water during the wet periods and that are otherwise well drained. For the greatest extent the soil is Jordan loam with a clay subsoil. In some areas hardpan is present as the subsoil. A few places are sandy. The water table is seldom less than 3 feet deep and in most areas 6 feet or more from the surface. Saline conditions cover a wide range and their consideration will be left for specific citation.

FLORISTICS.—The flora is diverse, often mixed, and in most regions forming certain well defined combinations that are rather constant over wide areas. Some of these combinations may be considered as associations while others less extensive and less well defined will be considered simply as plant communities. The following are recognized: greasewood-shadscale association (*Sarcobatus vermiculatus* and *Atriplex confertifolia*), shadscale association, *Kochia* flat association (*K. vestita* and *K. americana*), *Kochia-Suaeda* communities, *Sarcobatus-Grayia* communities, and rabbit-brush communities (*Chrysothamnus* spp.)

GREASEWOOD-SHADSCALE ASSOCIATION.—This is the most extensive association of the region and is second only to *Artemisia tridentata* as a basin type of vegetation. It grows in all quarters of the region, borders most parts of the Great American Desert, and is

TABLE XIII

PHYSICAL COMPOSITION OF SOILS OF GREASEWOOD-SHADSCALE ASSOCIATION
IN PERCENTAGE OF PARTICLES OF DIFFERENT SIZES IN TERMS OF
DRY WEIGHT AND H-ION CONCENTRATION

No.	LOCALITY	SOIL	DIAMETER OF PARTICLES (MM.)						PH
			6	5	3	2	1	$\frac{1}{2}$	
166	Tooele Valley	Loam	3.5	3.0	4.3	6.1	6.5	76.6	9.4
162	Tooele Valley	Clay	0.0	0.0	0.0	0.4	1.4	98.2	9.1
107	Jordan Valley	Loam	0.0	0.2	0.2	0.2	3.5	95.9	8.6
134	Farmington	Loam	0.4	1.3	2.8	11.8	26.2	57.5	8.9

TABLE XIV

WATER AND TOTAL SALTS CALCULATED IN PERCENTAGES OF DRY WEIGHT OF
SOILS FROM GREASEWOOD-SHADSCALE ASSOCIATION

No.	LOCALITY	SOIL AND SUBSOIL	WATER TABLE (FT.)	TOTAL SALTS (%) AT		
				1 IN.	2 FT.	3 FT.
24	Jordan Valley	Jordan loam	3	0.83	0.82	0.83
		Jordan clay				
37	" "	Jordan loam	3	0.75	0.82	0.82
		Jordan clay				
38	" "	Jordan loam	6	0.21	0.22	0.18
		hardpan				
39	" "	Jordan loam	6	0.26	0.18	0.18
		hardpan				

found generally in most saline situations throughout the west. It encroaches on both pioneer and intermediate floras of the strand and playas. The general aspect presents a scrubby vegetation 3-5 feet in depth with alternating patches of the greasewood and shadscale, the greasewood being the most extensive member. This plant has a much branched stem with white shreddy bark and green wood, and numerous spiny branches with terete fleshy leaves. The roots penetrate the soil to a depth of 10-15 feet and the plant is noted as a

ground-water indicator. It is also an indicator of black alkali, sodium carbonate.

The shadscale is a round-topped bush acquiring a height of 3 feet in its robust forms. The leaves are broad and thick with a silvery coat of scurfy scales. The physical factors governing this vegetation center around the alkali content of the soil and to a less extent the depth of the water table. Soil samples were taken from many localities, most of which show the conditions to be very similar. Tables XIII and XIV show the typical ranges of conditions.

The composition of this association varies in different localities, the areas approaching the lake showing a predominance of the Chenopodiaceae while the distal margins where the alkali is reduced show an abundance of grasses and annuals. The composition is as follows:

Dominant shrubs:

- Atriplex confertifolia* (Torr.) Wats.
- A. truncata* (Torr.) Gray
- A. nuttallii* Wats.
- Sarcobatus vermiculatus* (Hook.) Torr.
- Eurotia lanata* (Pursh) Moq.
- Kochia vestita* (Wats.) A. Nels.
- Suaeda moquinii* (Torr.) A. Nels.
- Chrysothamnus nauseosus* (Pall.) Brit.
- Tetradymia spinosa* H. & A.

Frequent herbs:

- Sclerochloa dura* (L.) Beauv.
- Aristida longiseta* Steud.
- Sitanion hystrix* (Nutt.) J. G. Smith
- Atriplex argentea* L.
- A. hastata* L.
- A. rosea* L.
- Amaranthus graecizans* L.
- Cleome lutea* Hook.
- C. serrulata* Pursh
- Opuntia fragilis* (Nutt.) Haw.
- O. polyacantha* K. Sch.

Cressa erecta Rydb.
Grindelia squarrosa (Pursh) Dunal
Ambrosia psilostachya DC.
Machaeranthera leucanthemifolia Greene
Lactuca integrata (Gren. & Godr.) A. Nels.
L. scariola L.

These plants include principally the perennials and such annuals as persist until late summer. The vernal aspect is remarkable in its number and density of short-lived annuals. The most dominant members include *Bromus hordeaceus*, *B. tectorum*, *Hordeum gussonianum*, and many species of the Cruciferae. In the early spring the flats are green but by the end of June these plants form a carpet of parched, tawny brown herbage. In various sections of the grease-wood-shadscale areas the density is different so that the predominance of the vernal types is variable. In dense stands of the shrubs the vernal plants are sometimes very scanty, while in areas where the shrubs are widely disposed the vernal growths are ample and rather suggest a shrubby grass flat community. The composition of the vernal flora is as follows:

Dominant species:

Bromus tectorum L.
B. hordeaceus L.
Hordeum gussonianum Parl.
Lepidium perfoliatum L.
Erodium cicutarium L'Her.

Subdominant species:

Lepidium dictyotum Gray
Hutchinsia procumbens (L.) Desv.
Capsella bursa-pastoris Medic.
Malcolmia africana (Willd.) A. Br.
Sophia pinnata (Walt.) Brit.
S. sophia L.
Camelina microcarpa Andrz.
Alyssum alyssoides (L.) Gouan.
Draba nemorosa L.
D. micrantha Nutt.

Thelypodium sagittatum (Nutt.) Endl.
Sisymbrium altissimum L.
S. asperum DC.
S. repandum L.
Lomatium platycarpum (Torr.) C. & R.
Aulospermum longipes (Wats.) C. & R.
Lappula redowskii occidentalis (Wats.) Rydb.
Castilleja linariaefolia Benth.
Adenostegia sp.
Plantago elongata Pursh
P. purshii Roem. & Schult.
Matricaria suaveolens (Pursh) Buchanan

Mosses:

Pterygoneurum cavifolium (Ehrh.) Jur.
Tortula ruralis Ehrh.
T. subulata inermis B. & S.
Pottia nevadense Card. & Ther.
Funaria hygrometrica (L.) Sibth.
F. calcarea Wahl.
Bryum caespitium L.
B. inclinatum (Sw.) Bland.
B. pendulum (Hornsh.) Schimp.

The variety of plants is much greater on the east side of the lake than on the west side, since the east side receives about 10 inches more annual rainfall than the western part. The valleys along the southern and western sections of the lake show the association at its best. In Curlew and Hansel valleys on the northwestern borders the plants are not so robust, but present a monotonous combination of green and silvery gray for miles. The water table is remote except along the immediate lake borders. The annuals are fewer and the grasses less prominent. The dominant plants are more evenly balanced, the notable ones being as follows:

Common species:

Atriplex truncata (Torr.) Gray
A. nuttallii Wats.
A. saccaria Wats.

A. falcata (Jones) Standl.
Grayia spinosa (Hook.) Moq.
Suaeda moquinii (Torr.) A. Nels.
S. intermedia Wats.
S. diffusa Wats.
Kochia vestita (Wats.) A. Nels.
Eurotia lanata (Pursh) Moq.

Frequent species:

Eriocoma cuspidata Nutt.
Sitanion hystrix (Nutt.) J. G. Smith
Eriogonum pusillum T. & G.
Opuntia sp.
Gutierrezia microcephala Gray
Chrysothamnus nauseosus (Pall.) Brit.
Artemisia tridentata Nutt.
A. spinescens Eat.

A remarkable stand of greasewood and shadscale is found bordering the old lake shore in the Lakeside Mountain region. In most places it has the normal aspect as to depth of vegetation and density, but there is one tract which shows a relatively pure stand of large greasewoods which attain a height of 10 feet. The composition is somewhat varied by a greater abundance of *Tetradymia*, *Grayia*, and *Opuntia*.

The greasewood-shadscale association is the edaphic climax vegetation of the Great Salt Lake region. At its outer limits it is invaded mainly by *Artemisia tridentata* and by a mixed grass-shrub community of plants that is not very well defined. It is not a permanent vegetation but one of long duration. The guarantee of its persistence is alkali. Physical forces are continually but slowly reducing the salt content of the soil. The chief agencies are wind and water. The former removes vast amounts during dust storms and deposits non-saline dust from other regions; the latter tends to carry the salt in solution to the lake and deposit non-saline detritus from the hills above. The reaction of the plants to the reduction of alkali is a critical point which may be of short or long duration, depending upon conditions. Where halophytes are partially covered by flood deposits

they may persist, but new progeny are forced out by the non-saline types. The broad plains are slow in giving up the alkali, and only near the outer borders is the ingress of non-halophytes creating sharp and critical competition. The halophytes lose ground mainly through lack of progeny to maintain the hold established when saline conditions were nearer the optimum. Upsetting the equilibrium which guarantees the persistence of the halophyte reduces its relative competitive power, and thus it is forced closer and closer to the center of the alkali. It is another phase in the dynamics of vegetation which covers long periods of time. With the slow procession crowding the halophytes ever closer to the lake, and with the possible extinction of the lake, they are destined to occupy a much smaller area than they now hold. Successions in remote regions may arise and culminate, perhaps perish, before the lowest point on the Great Salt Lake basin is reclaimed by a non-halophytic vegetation climax. Whether this will ever occur can be left only to conjecture. Diastrophism may cut it short, or a change in climate may refill Great Salt Lake.

SHADSCALE ASSOCIATION.—Extensive stands of the shadscale frequently occur on the distal margins of the greasewood-shadscale associations. The general aspect presents a low shrubby vegetation, but the plants are usually rather widely disposed. It is essentially a flora of dry, mildly saline soils. Abundant ground water is necessary to support greasewood and many other halophytes, but *Kochia*, *Eurotia*, and many species of *Atriplex* have the capacity to grow in dry soils. High well drained ground and particularly long alluvial slopes are favorable for development of the shadscale association. Regions of this character are found in Tooele Valley, the valleys bordering the Great American Desert, and in Curlew Valley. *Atriplex confertifolia* is the dominant shrub. The vernal flora is much like that described in the preceding association. The composition of the summer aspect is as follows:

Shrubs:

Atriplex confertifolia (Torr.) Wats.

A. nuttallii Wats.

A. truncata (Torr.) Gray

Eurotia lanata (Pursh) Moq.

Kochia vestita (Wats.) A. Nels.

Tetradymia spinosa H. & A.
T. nuttallii T. & G.
Artemisia spinescens Eat.
Chrysothamnus pumilus Nutt.
C. nauseosus (Pall.) Brit.
Gutierrezia microcephala Gray

Herbs:

Poa sandbergii Vasey
Festuca octoflora Walt.
Bromus tectorum L.
Agropyron tenerum Vasey
Eriogonum cernuum Nutt.
E. sp.
Salsola pestifer A. Nels.
Amaranthus graecizans L.
Lepidium perfoliatum L.
Draba nemorosa L.
D. micrantha Nutt.
Arabis holboellii Hornem.
Malcolmia africana (Willd.) R. Br.
Cleome lutea Hook.
Astragalus utahensis T. & G.
Sphaeralcea grossularieafolia (H. & A.) Rydb.
Opuntia sp.
Chrysopsis foliosa Nutt.
Aster sp.
Antennaria sp.

KOCHIA FLAT ASSOCIATION.—*Kochia* is a small shrub seldom more than 1 foot high with a more or less herbaceous upper stem and a woody base. The leaves are narrow, slightly fleshy, and covered with long soft hairs. There are two species in this region, *K. vestita* and *K. americana*. The general aspect of the association is a low shrub of grayish color and relatively few associates. The ground is usually exposed more than in most associations and communities. The soil relations are shown in table XV.

Kochia is not a particularly deep rooting plant and typically feeds

on precipitation water. In nearly all places where it occurs as an association the flats are dry and well drained. Tooele, Skull, and Curlew valleys show the association at its best. Most of the associated

TABLE XV
ANALYSIS OF SOILS OF KOCHIA FLAT ASSOCIATION. SALTS IN TERMS
OF DRY WEIGHT OF SOIL

No.	LOCALITY	SOIL SUBSOIL	PH	TOTAL SALTS (%) AT		
				1 IN.	2 FT.	3 FT.
17	Skull Valley	Jordan clay	8.4	1.62	1.64	
17a	Skull Valley	Jordan clay	8.4	1.03	1.16	1.30
26	Jordan Valley	Jordan loam hardpan	8.2	0.26	0.27	0.26
64	Tooele Valley	Jordan loam Jordan clay	8.6	0.84	0.86	0.86

plants are the same as previously listed but occur in different degrees of abundance. The following are the commonest members:

Shrubs:

Kochia vestita (Wats.) A. Nels.
K. americana Wats.
Eurotia lanata (Pursh) Moq.
Atriplex truncata (Torr.) Wats.
A. nuttallii Wats.
Tetradymia glabrata Gray
T. spinosa H. & A.

Herbs:

Poa sandbergii Vasey
Deschampsia danthonioides Munr.
Bromus tectorum L.
Lepidium perfoliatum L.
Plantago purshii Roem. & Schult.

KOCHIA-EUROTIA COMMUNITIES.—This community is merely a rather well defined variation of the *Kochia* flat association, differing mainly in having *Eurotia* in equal dominance with *Kochia*. The community is generally denser than the preceding association but the species are about the same.

KOCHIA-SUAEDA COMMUNITIES.—This is another variation of the *Kochia* flat association, occurring in local areas of dry and rather strongly saline soil. The general aspect is darker than the preceding community, with *Suaeda depressa*, *S. diffusa*, and an occasional greasewood forming the principal members. Other species are few and widely scattered.

RABBIT-BRUSH COMMUNITIES.—As one of the most prominent plants of the lowlands, the rabbit-brush finds an important rôle in many associations and by itself often constitutes the dominant aspect in certain localities. It is essentially a ground water indicator and thrives in mildly saline soils. Its limits of tolerance vary with the type of alkali present. In the Great Salt Lake region where chlorides and carbonates are strong its range appears to be between 0.1 to 0.3%, although in local places it has been observed to grow in soils bearing as high as 0.8% salt. The Tooele Valley study (7) reports an average of 0.3%, while in other regions in the state it has been reported in soils of 3.15% salt (8). When high concentrations are found gypsum is usually the principal salt.

The most extensive rabbit-brush communities are located in Tooele and Blue Spring valleys. Frequently it is associated with greasewood or *Sporobolus*. On Stansbury Island it commonly grows with the greasewood on the flats and with the sage on the higher levels. It is one of the dominant plants of sand dunes. Scattered growths occur in nearly all parts of the region along the junction between alkaline and non-alkaline soils.

The general aspect presents a community of somewhat open growth with caespitose erect stems 3-4 feet high, the individuals rather evenly disposed. Grasses and small herbs usually occupy the intervening spaces. The composition is as follows:

Principal species:

- Chrysothamnus pinifolius Greene
- C. viscidiflorus tortifolius (Gray) Greene
- C. nauseosus (Pall.) Brit.
- C. puberulus (Eat.) Greene
- C. graveolens (Nutt.) Greene
- C. pulcherrimus Greene

Sporobolus airoides (Torr.) Gray
Distichlis spicata (L.) Greene

Frequent species:

Bromus tectorum L.
Allium acuminatum Hook.
Zygadenus paniculatus Wats.
Comandra pallida DC.
Kochia vestita (Wats.) A. Nels.
Atriplex hastata L.
A. confertifolia (Torr.) Wats.
Eurotia lanata (Pursh) Moq.
Sarcobatus vermiculatus (Hook.) Torr.
Suaeda moquinii (Torr.) A. Nels.
Lepidium perfoliatum L.
Camelina microcarpa Andrz.
Sophia sophia L.
Malcolmia africana (Willd.) R. Br.
Erodium cicutarium L'Her.
Opuntia fragilis (Nutt.) Haw.
Grindelia squarrosa (Pursh) Dunal
Aster leucanthemifolius Greene
Artemisia tridentata Nutt.
A. gnaphalodes Nutt.
Cirsium scariosum Nutt.
Lactuca integrata (Gren. & Godr.) A. Nels.

Dunes

The dunes of Great Salt Lake are formed of two kinds of sand, calcareous oolitic sand and fine-grained siliceous sand. Considerable stress was laid on the formation of calcareous deposits through the precipitation of calcium carbonate from the lake waters in the earlier part of this paper. All of the dunes bordering the lake are of the calcareous type while those removed from the lake are of the siliceous type.

SALTAIR SECTION.—Extending from Saltair to the Jordan Delta is a series of low dunes of calcareous character. The grains are coarse and often mixed with a stony element derived from hardpan. The

finer material shows more than 98% particles less than 0.5 mm. in diameter by dry weight, while the coarser material averages a little over 50% particles of this size. The alkali content is shown in table XVI.

The general aspect presents the light colored oolitic and hardpan material dotted with shrubs and tufts of grass while a variety of small herbs are scattered between. The greasewood and rabbit-brush are the dominant shrubs and *Eriocoma* and *Sporobolus* the dominant

TABLE XVI
WATER AND CHEMICAL ANALYSIS OF OOLITIC DUNE DEPOSIT OF
SALT AIR SECTION. SALTS CALCULATED IN TERMS
OF DRY WEIGHT OF SAMPLES

DEPTH	WATER CONTENT	NaCl	NaCO ₃	NaHCO ₃	Na ₂ SO ₄	TOTAL SALTS
4 in.	4.59	0.16	0.057	Trace	0.497	0.62
2 ft.	12.81	0.255	0.100	0.01	0.284	0.64

herbs. In local depressional areas the salt grass, samphires, and ink-weeds become prominent. The older dunes show a mixed plant community with both halophytic and non-halophytic plants growing together with no apparent diminution in vigor or robustness. The composition is as follows:

Shrubs:

Atriplex confertifolia (Torr.) Wats.
A. canescens (Pursh) James
A. truncata (Torr.) Gray
Sarcobatus vermiculatus (Hook.) Torr.
Gutierrezia microcephala Gray
Chrysothamnus pulcherrimus Greene

Frequent herbs:

Eriocoma cuspidata Nutt.
Sporobolus airoides Torr.
Distichlis spicata (L.) Greene
Bromus tectorum L.
Poa sp.
P. sandbergii Vasey

Sitanion hystrix (Nutt.) J. G. Smith
Atriplex hastata L.
Salsola pestifer A. Nels.
Abronia salsa Rydb.
Sphaerostigma utahensis Small
Chaenactis stevioides H. & A.

STANSBURY ISLAND DUNES.—On the west side of the island extending from the middle to the northern extremity is a series of dunes. It varies in width up to nearly 300 yards and varies in depth up to 15 or 18 feet. The sand is of the oolitic calcareous type, white on the surface, but at 2 or 3 feet in depth it is of finer texture and brownish in color. There is also a siliceous element at this depth. At the northern end the light material has been blown high up on the rocky hillside. Presumably the deposits rest on a level saline plain.

The floral aspect is dominated by two plant types. The southern part shows a scattered shrub community dominated by greasewood and rabbit-brush while toward the north *Juniperus utahensis* offers an interesting and unique situation. Many typical dune species are to be noted in *Eriocoma*, *Eriogonum*, *Abronia*, and the Onagraceae. The moss *Tortula ruralis* may be properly classed as a dominant member, great tufts occurring frequently under shrubs and on the north-facing slopes.

The shrubby areas may be traced by the prominent white color of *Chrysothamnus puberulus*, which is robust in habit and lends a distinct character to the vegetation as a whole. The composition of the shrubby community is as follows:

Dominant shrubs:

Sarcobatus vermiculatus (Hook.) Torr.
Atriplex canescens (Pursh) James
Chrysothamnus puberulus (Eat.) Greene

Frequent shrubs:

Grayia spinosa (Hook.) Moq.
Chrysothamnus lanceolatus Nutt.
C. stenophyllus (Gray) Greene
C. viscidiflorus (Hook.) Nutt.
C. viscidiflorus tortifolius (Gray) Greene

Frequent herbs:

Eriocoma cuspidata Nutt.
Sporobolus cryptandrus (Torr.) Gray
Bromus tectorum L.
Agropyrum tenerum Vasey
Elymus condensatus Presl.
Comandra pallida DC.
Eriogonum cernuum Nutt.
E. ovalifolium Nutt.
Salsola pestifer A. Nels.
Abronia fragrans Nutt.
A. micrantha Torr.
Erysimum sp.
Astragalus utahensis T. & G.
Mentzelia acuminata (Rydb.) Tidest.
M. laevicaulis (Dougl.) T. & G.
Pachylophus sp.
Sphaerostigma utahensis Small
Ptiloria exigua (Nutt.) Greene
Chylisma parryi (Wats.) Small
Leptodactylon pungens (Torr.) Wats.

The depressions are more alkaline, as indicated by the presence of *Distichlis* and *Sporobolus*. *Bryum* sp. is also found here.

The northern half of the dunes shows the entrance of the juniper, which is slowly invading the shrubby communities, the first entrants being small and shrubby. The species just listed persist, although fewer in numbers, as the junipers become more and more dominant. As the dunes become larger the trees increase in size and numbers in proportion. In addition to the plants cited, the juniper community has the following:

Juniperus utahensis (Engelm.) Sarg.
Hordeum pusillum Nutt.
H. maritimum With.
Chenopodium album L.
Atriplex rosea L.
Erodium cicutarium L'Her.
Rhus trilobata Nutt.

The presence of the juniper is a point of special interest in that it marks the closest approach of trees to the lake. Its tolerance of mild concentrations of alkali is well known in other parts of the state, where it reaches its maximum development.

LAKESIDE MOUNTAIN DUNES.—One of the most interesting dune areas is that paralleling the base of the Lakeside Mountains, about 2 miles from the old lake shore. They are mainly siliceous and of a very fine tan-colored sand. While their origin is obscure, they may have been calcareous dunes at one time and have since had the calcium washed away, leaving the siliceous nuclei of the original oolite.

Sarcobatus and *Atriplex canescens* are the commonest shrubs. The open places show many characteristic species, among which are *Eriocoma*, *Eriogonum cernuum*, *Rumex venosus*, *Abronia salsa*, *A. cycloptera*, a species of *Psoralea*, and *Chamaesyce flagelliformis*. The following list shows the composition:

Shrubs:

Atriplex canescens (Pursh) James
A. confertifolia (Torr.) Wats.
Grayia spinosa (Hook.) Moq.
Chrysothamnus viscidiflorus tortifolius (Gray) Greene
Artemisia tridentata Nutt.
Tetradymia spinosa H. & A.

Frequent herbs:

Eriocoma cuspidata Nutt.
Sitanion hystrix (Nutt.) J. G. Smith
Eriogonum cernuum Nutt.
Rumex venosus Pursh
Chenopodium album L.
C. fremontii Wats.
C. sp.
Atriplex rosea L.
Amaranthus graecizans L.
Abronia salsa Rydb.
A. cycloptera Gray
Erysimum sp.
Cleome lutea Hook.

Psoralea lanceolata Pursh (?)
Chamaesyce flagelliformis (Engelm.) Rydb.
Opuntia fragilis (Nutt.) Haw.
Oenothera sp.
Chylisma parryi (Wats.) Small
Leptodactylon pungens (Torr.) Nutt.
Cryptanthe sp.
Solanum triflorum Nutt.
Marrubium vulgare L.
Machaeranthera sp.
Ptiloria exigua (Nutt.) Greene
Helianthus annuus L.

Tortula ruralis is the only moss.

Salt marshes and sloughs

Salt marshes and sloughs may arise in a variety of ways. They occur in localities where the water table is very close to the surface, where fresh water or saline springs and wells have their outlets. Tooele, Jordan, and Malad valleys are the principal localities, while numerous smaller areas are to be found in other places.

Analyses of the soils from the margins and beds of marshes and sloughs show conditions to be much like those already cited. Toward the outer limits of the alkali belt all gradations of saline quality of the soil may be observed, from those strongly impregnated with alkali to those that are comparatively sweet. The H-ion concentration of both soil and water shows much the same reactions as noted before. Table XVII gives a list of localities and the pH concentrations. Analyses of the waters from the principal mineral springs are given in the section dealing with hot mineral springs.

BLACK ROCK-TOOELE VALLEY MARSHES.—Topography plays a rôle in some places. At Black Rock, springs are found along the base of a steep headland so that extremes in alkalinity are found within a very short range. Southward and entering Tooele Valley the marshes are established in the depressions. The floral aspects are much the same as in most marshes in this region, with rushes and cattails lending the usual dominating characteristics. The features of contrast are noted mainly in subsidiary types. In this instance the

algae are of particular interest, showing types that are adjusted to mildly saline water. Among the specimens collected are two species of *Enteromorpha* which are abundant in some places and *Spirogyra*

TABLE XVII

H-ION CONCENTRATION OF SOILS AND WATERS FROM VARIOUS SALT MARSHES, SLOUGHS, AND SPRINGS OF GREAT SALT LAKE REGION

No.	TYPE OF VEGETATION	LOCALITY	SOIL OR WATER	PH
157	Batrachospermum	Jordan Valley	Spring water	7.4
154	Radicula, Glaux, Glycyrrhiza	" "	Black loam	7.8
155	Scirpus olneyi	" "	" "	8.6
156	Sporobolus	" "	" "	7.6
105a	Cladophora, etc.	" "	Well water	7.6
105	Distichlis	" "	Slough clay	8.8
100	River water	Jordan River	Water	8.0
135	Distichlis	Farmington	Slough clay	8.5
188	Barren	Jordan Valley	Slough bed	8.4
189	Allenrolfea	" "	Slough margin	8.6
190	Suaeda occidentalis, Bryum, etc.	" "	" "	8.4
191	Allenrolfea	" "	" "	9.2
193	Distichlis	" "	" "	8.6
194	Chara, Typha, Scirpus	" "	Salt marsh	8.6
195	Distichlis, Sida, etc.	" "	Marl loam	8.4
196	Atriplex hastata	" "	" "	8.2
197	Scirpus, Aster angustus, etc.	" "	" "	8.2
199a	Myxophyceae	" "	Well water	8.3
202	Scirpus paludosus	" "	Slough bed	8.5
203	Distichlis, Suaeda	" "	" "	8.3
204	Myxophyceae	" "	Hot spring	8.4

and *Cladophora* which are abundant in other places. The algal flora is:

Myxophyceae:

Aphanothece nidulans Rich.

Tolypothrix tenuis Kz.

Chlorophyceae:

Chlamydomonas spp.

Cladophora spp.

Enteromorpha intestinalis L.

E. plumosa Kz.

Potamogeton pectinatus was the only submerged vascular plant found. The emergent members form dense and extensive societies. The rushes are most prevalent in the more strongly saline portions

of the marsh while cattails are restricted to the margins where the salt is not so concentrated. The following plants were listed:

Typha latifolia L.
T. angustifolia L.
Scirpus americanus Pers.
S. lacustris L.
S. olneyi Gray
S. paludosus A. Nels.
Eleocharis palustris (L.) R. & S.

The muddy banks generally show a mixture of true halophytes and plants of sweet soils. The grasses are usually dominant. This society includes:

Eleocharis acicularis (L.) R. & S.
Polypogon monspeliensis (L.) Desf.
Distichlis spicata (L.) Greene
Puccinellia nuttalliana (Schultes) Hitchc.
Juncus balticus Willd.
Carex nebraskensis Dewey
Rumex persicarioides L.
R. crispus L.
Atriplex hastata L.
Halerpestes cymbalaria (Pursh) Greene
Radicula nasturtium-aquaticum (L.) Brit. & Rendle
Cicuta occidentalis Greene
Berula erecta (Huds.) Coville

Conjunctive with the marshes are meadow-like societies harboring many grasses and a wide variety of other plants. The components include:

Triglochin maritima L.
T. palustre L.
Sporobolus asperifolius (Nees & Mey.) Thurb.
S. airoides Torr.
S. confusus (Fourn.) Vasey
Polypogon monspeliensis (L.) Desf.
Spartina gracilis Trin.
Beckmannia erucaeformis (L.) Host.

Phragmites communis Trin.
Puccinellia nuttalliana (Schultes) Hitchc.
Hordeum jubatum L.
Bromus tectorum L.
Distichlis spicata (L.) Greene
Juncus balticus Willd.
Rumex persicarioides L.
R. crispus L.
R. britannica L.
Atriplex hastata L.
Bassia hyssopifolia (Pall.) Kuntze
Abronia salsa Rydb.
Myosurus apetalus Gay
Ranunculus eremogenes Greene
Halerpestes cymbalaria (Pursh) Greene
Spergularia rubra (L.) J. & C.
S. salina Presl.
Glaux maritima L.
Dodecatheon salinum A. Nels.
Gaura parviflora Dougl.
Onagra hookeri (Torr. & Gray) Small
Asclepias speciosa Torr.
Castilleja stricta Rydb.
Adenostegia ramosa (Nutt.) Greene
Iva axillaris Pursh
Helianthus annuus L.

The abrupt slopes of the headlands make a narrow conjunctive belt with the marshes and springy areas which is much reduced in alkali content so as to present a different community of plants:

Hordeum jubatum L.
Salix exigua Nutt.
Urtica breweri Wats.
Atriplex rosea L.
Sophia pinnata (Wats.) Brit.
Sisymbrium altissimum L.
Cleome serrulata Pursh

Rosa melina Greene
Melilotus alba Desv.
Trifolium repens L.
Glycyrrhiza lepidota Pursh
Rhus trilobata Nutt.
Onagra hookeri (T. & G.) Small
Berula erecta (Huds.) Coville
Asclepias speciosa Torr.
Cuscuta sp. on *Helianthus* et al.
Cressa erecta Rydb.
Marrubium vulgare L.
Castilleja linariaefolia Benth.
C. exilis A. Nels.
Rubia tinctoria L.
Grindelia squarrosa (Pursh) Dunal
Iva axillaris Pursh
Ambrosia psilostachya DC.
Xanthium pennsylvanicum Wallr.
Helianthus annuus L.
Helenium autumnale L.
Crepis runcinata T. & G.
Lactuca integrata (Gren. & Godr.) A. Nels.
L. scariola L.

MALAD VALLEY AND BLUE SPRING HILLS SECTION.—This region includes extensive marsh lands, many of which have been extended artificially for the purpose of maintaining them as bird sanctuaries. As in the case of the river deltas, several plants beneficial to birds have been introduced. *Ruppia*, *Potamogeton*, *Sparganium*, *Puccinellia*, and several rushes are the principal ones. In general these marshes are similar in plant types although they differ in minor respects. The following species were peculiar to this section:

Sparganium eurycarpum Engelm.
Lemna minor L.
Spirodela polyrrhiza (L.) Schleich.
Potamogeton natans L.
Ruppia maritima L.

Echinochloa crus-galli (L.) Beauv.
Scirpus validus Vahl.
Carex stipata Willd.
Polygonum emersum (Michx.) Brit.
Epilobium adenocaulon Hausskn.
Helianthus nuttallii T. & G.

SLOUGHS

Sloughs occur chiefly in Jordan Valley. They differ from the marshes in being poorly drained, are generally more saline, and the grasses replace the rushes and cattails as the dominant types. There are numerous plants distributed in many families. The bottoms are muddy with flocculent masses of black muck consisting of finely divided vegetal matter mixed with clay. The algal flora of these situations is of particular interest. In general those areas strongly alkaline have a preponderance of Myxophyceae while localities less alkaline show a decided increase in Chlorophyceae. Wherever sloughs are maintained by wells or springs of mineral water Myxophyceae are also the dominating algae. The following is a composite list:

Myxophyceae:

Oscillatoria amphibia Ag.
O. animalis Ag.
O. amoena (Gom.) Kz.
O. chalybea Mert.
O. janthophora
O. nigro-viridis Thw.
O. subtilissima Kuetz.
O. spp.
Phormidium angustissimum W. & G. S. West
P. foveolarum (Gom.) Mont.
P. fragilis Menegh.
P. ramosum P. Boye
Aphanothece calthrata West
A. nidulans Rich.
Anabaena spp.
Lyngbya martensiana Menegh.

L. aeruginea-caerulea (Kuetz.) Gom.
Tolypothrix tenuis Kz.
Nostoc pruniforme (L.) Ag.
N. spp.

Chlorophyceae:

Ulothrix zonata (?)
U. spp.
Spirogyra spp. (five species indet.)
Zygnema spp.
Oedogonium spp.
Rhizoclonium hieroglyphicum Kz.
Nephrocystium agardhianum Nag.
Gloeocystopsis limneticus Am.
Cladophora fraeta forma
C. spp.
Enteromorpha intestinalis L.
E. plumosa Kz.

Rhodophyceae:

Batrachospermum spp.

Charaphyceae:

Chara foetida L.
C. fragilis ?

Several other species were included in the collections to which no definite names could be assigned. This was particularly true of the unicellular forms.

Among the vascular plants the grasses are the dominant types, the salt grass being almost exclusive in this respect in most localities. Most of the species listed for the marshes occur on the margins of adjacent areas. Besides the plants listed previously the following were noted for the sloughs alone:

Poa nevadensis Vasey
Elymus glaucus Buckley
E. triticoides Buckley
Juncus nevadensis Wats.
Polygonum ramosissimum Michx.

P. convolvulus L.
P. aviculare L.
Chenopodium album L.
C. glaucum L.
C. leptophyllum (Moq.) Nutt.
Atriplex falcata (Jones) Standl.
A. nitens
Suaeda depressa (Pursh) Wats.
S. intermedia Wats.
S. moquinii (Torr.) A. Nels.
Amaranthus blitoides Wats.
Sesuvium sessile Pers.
Lepidium perfoliatum L.
Sida hederacea (Dougl.) Torr.
Apocynum cannabinum L.
Asclepias incarnata L.
Cressa erecta Rydb.
Marrubium vulgare L.
Aster frondosus (Nutt.) T. & G.
A. angustus T. & G.

Hot mineral springs

Hot springs are found along the base of the Wasatch Mountains and at the south end of the Blue Spring Hills. The origin of these springs is believed to have been brought about through faulting in which a great amount of heat was generated by the friction. The great depth serves as insulation while the crushed rocks along the fault plane serve to collect percolating waters.

The temperature of the water varies from 34° to 61° C. While sulphurous in quality the dominant constituent is sodium chloride in every case. The H-ion concentration varies from 8.2 to 8.8. Analyses of the most important springs are given in table XVIII. The discharge from some of these springs is considerable, the largest two being Beck's Hot Spring and a spring near the town of Honeyville. The water wells up in great volume with a characteristic sulphurous odor.

The flora of the springs proper is exclusively of Myxophyceae

while in the outlets a limited number of Chlorophyceae and vascular plants occur. There is a rather marked uniformity in the species inhabiting the various springs, although the larger springs show the richest and most varied flora. *Oscillatoria amphibia* and *O. animalis*

TABLE XVIII

ANALYSES OF WATERS FROM HOT MINERAL SPRINGS OF GREAT SALT LAKE REGION, IN TERMS OF P.P.M., EXCEPT D WHICH IS PERCENTAGE (2)

	A	B	C	D	E	F	G
Ca	694.3	141.5	535.2	4.90	901.0	1174.0	878.0
Mg	109.5	27.7	138.4	0.4	218.0	28.0	379.0
Na	3754.9	405.0	3039.0	30.38	16595.0	8563.0	10426.0
K	196.9	55.0	178.0	3.76			
Al ₂ O ₃	9.0			0.02			
Fe ₂ O ₃		5.1	0.7				
SiO ₂	31.5	50.5	21.3	0.20			
SO ₄	840.5	53.8	787.5	0.94	497.0	203.0	20.0
HCO ₃	204.8	272.7	442.9	0.61	454.0	186.0	393.0
CO ₂							
Cl	6743.8	635.6	4968.0	58.79	27081.0	15079.0	18460.0
Fe					1.0	1.0	2.0
Total	12584.9	1658.0	10284.0	23309.0	45541.0	25300.0	30440.0

A. Beck's Hot Spring, Temp. 133°F. BRIGGS, B. R., U.S.G.S. Bull. 42. 148. 1878.

B. Sandy Hot Springs, 8 miles south of Salt Lake City. KINGSBURY, J. T., 1882.

C. Warm Springs, Salt Lake City. KINGSBURY, J. T., 1881.

D. Utah Hot Springs, 8 miles north of Ogden. Temp. 55° C. CLARKE, F. W., U.S.G.S. Bull. 9. 30. 1884.

E. Hot Spring at Honeyville, Boxelder Co. BAILEY, J. R.

F. Sanitarium Hot Springs, Boxelder Co. BAILEY, J. R.

G. Hot Spring at south end of Little Mountain (north of Bear River Bay). BAILEY, J. R.

were found in every spring investigated. The following is a composite list of all the springs:

Oscillatoria amphibia Ag.

O. amoena (Gom.) Kuetz.

O. animalis Ag.

O. brevis var. *neapolitana* (Kuetz.) Gom.

O. chalybea Mert.

O. janthophora

O. laetevirens Crouan.

O. lemmermannii Wolosz.

any one or two types as representative of the region. *Distichlis*, *Sporobolus*, species of *Suaeda* and of *Atriplex* cover such a wide and diverse area that tracing a uniform line is almost impossible. They occur in nearly every combination as the intermediate successional stage. The diagram shown in figure 1 shows the actual successions of some of the larger and representative localities from various points around the lake.

The floristic features are tabulated in tables XIX and XX. In the first are listed the number of species in each family showing four relative degrees of halophytism. Column I includes all those that are absolute halophytes found only in alkaline soil; column II includes plants essentially halophytes but with a wide range of toleration; column III is a group of plants essentially non-halophytic but frequently inhabiting saline areas; column IV includes such plants as are seldom found in halophytic regions. According to this estimate, 54.3% of the flora is essentially halophytic and 45.7% essentially non-halophytic but with a certain degree of alkali tolerance.

Table XX indicates the geographic relations as to extent of distribution. The endemic species are those occurring only within a 100-mile radius of Great Salt Lake; the western species are those of the Rocky Mountain region and westward. A little over half of the flora is typically western.

Summary

1. The rocks of the Great Salt Lake region embrace a wide range of igneous, sedimentary, and metamorphic members. Historically they extend from the Archean to the Eocene, with nearly every period represented.

2. Great Salt Lake had its origin in a large Pleistocene lake named Lake Bonneville. It covered an area of 19,750 square miles and at its highest level stood about 1000 feet above the present level of Great Salt Lake. It was partially drained by erosion of the outlet and then by evaporation and seepage.

3. The climate shows an annual precipitation of about 6-7 inches in the western portion of the region and about 16-17 inches in the eastern portion. Evaporation amounts to about 68.67 inches a year, with an average wind movement of 69,139 miles yearly. The growing season free from frost averages approximately 160 days and the annual average temperature is about 50° F.

TABLE XIX

	I	II	III	IV	TOTAL
Pinaceae.....			1		1
Gnetaceae.....			2		2
Typhaceae.....			2		2
Sparganiaceae.....			1		1
Lemnaceae.....				1	1
Naiadaceae.....		2	1	1	4
Juncaginaceae.....			2		2
Alismaceae.....			2		2
Gramineae.....	7	14	12	5	38
Cyperaceae.....	2	7	4		13
Juncaceae.....		1	2		3
Liliaceae.....				3	3
Melanthaceae.....			1		1
Salicaceae.....				3	3
Urticaceae.....			2		2
Polygonaceae.....		3	7	3	13
Chenopodiaceae.....	22	8			30
Amaranthaceae.....		1	1	1	3
Nyctaginaceae.....		3	2		5
Aizoaceae.....	1				1
Caryophyllaceae.....	1	1			2
Ranunculaceae.....	1	1	3	1	6
Cruciferae.....		14	6	3	23
Capparidaceae.....		2		1	3
Rosaceae.....				1	1
Pomaceae.....				1	1
Leguminosae.....		3	6	1	10
Geraniaceae.....			1		1
Euphorbiaceae.....		1	2		3
Anacardiaceae.....				1	1
Malvaceae.....	1	3			4
Loasaceae.....			1	2	3
Cactaceae.....		2	2		4
Onagraceae.....	1	4	3	2	10
Haloragidaceae.....				1	1
Umbelliferae.....		1	5	2	8
Primulaceae.....	2				2
Apocynaceae.....			1	1	2
Asclepiadaceae.....		1	3	1	4
Cuscutaceae.....					1
Convolvulaceae.....	2		2		4
Polemoniaceae.....		2	1	3	6
Boraginaceae.....	2	3		1	6
Verbenaceae.....			1	1	2
Labiatae.....		1		1	2
Solanaceae.....		2			2
Scrophulariaceae.....	1	2	2	3	8
Orobanchaceae.....			1		1
Plantaginaceae.....		2		1	3
Rubiaceae.....			1		1
Compositae.....	1	42	16	12	71
Total.....	44	130	94	59	326
Percentage.....	13.5%	40.8%	27.9%	17.8%	

TABLE XX

	ENDEMIC	WESTERN	NORTH AMERICAN	COSMO- POLITAN	DISJUNCT
Pinaceae.....		1			
Gnetaceae.....		2			
Typhaceae.....				2	
Sparganiaceae.....				2	
Lemnaceae.....				1	
Naiadaceae.....				4	
Juncaginaceae.....				2	
Alismaceae.....			1	2	
Gramineae.....		13	12	13	1
Cyperaceae.....		1	4	8	
Juncaceae.....			1	2	
Liliaceae.....		3			
Melanthaceae.....		1			
Salicaceae.....			3		
Urticaceae.....		1	1		
Polygonaceae.....		3	3	7	
Chenopodiaceae.....	2	18	4	5	1
Amaranthaceae.....		1		2	
Nyctaginaceae.....		4	1		
Aizoaceae.....		1			
Caryophyllaceae.....		1	1		
Ranunculaceae.....		3	2	1	
Cruciferae.....		8	4	10	1
Capparidaceae.....			2	1	
Rosaceae.....		1			
Pomaceae.....	1				
Leguminosae.....	1	3	1	5	
Geraniaceae.....				1	
Euphorbiaceae.....		1		2	
Anacardiaceae.....		1			
Malvaceae.....		3	1		
Loasaceae.....		3			
Cactaceae.....		3	1		
Onagraceae.....	1	8		1	
Haloragidaceae.....				1	
Umbelliferae.....		5	2	1	
Primulaceae.....		1		1	
Apocynaceae.....				2	
Asclepiadaceae.....		3	2		
Convolvulaceae.....		2			
Polemoniaceae.....		6			
Boraginaceae.....		6			
Verbenaceae.....			1	1	
Labiatae.....			2		
Solanaceae.....		1		1	
Scrophulariaceae.....		5		3	
Orobanchaceae.....		1			
Plantaginaceae.....			2	1	
Rubiaceae.....				1	
Compositae.....	4	45	9	13	
Total.....	9	160	59	97	3
Percentage.....	2.4%	48.7%	18.1%	29.2%	0.6%

4. At present Great Salt Lake is about 75 miles long and 38 miles wide, with an average depth of 15 feet, the deepest point being about 40 feet. The brine consists principally of sodium chloride with smaller amounts of potassium, magnesium, and calcium salts. The percentage varies with the fluctuation of lake level, showing approximately 1% for every foot increase or decrease. At its highest level it showed 13.8% and at its lowest level 27.72%.

5. Floristically the region is characterized by the absence of trees, by broad barren salt flats bordered with succulent salt plants, and by a low shrubby vegetation on the saline plains.

6. The lake water proper harbors six species of algae, four Myxophyceae and two Chlorophyceae. *Aphanothece utahensis* and *Microcystis packardii* are the commonest species and are directly concerned with the formation of a tufa-like deposit which later forms a hardpan. *Chlamydomonas* sp. is abundant also.

7. The strand flora consists mainly of two invading genera, *Salicornia* and *Allenrolfea*. The former tolerates salt up to 6%, the commonest amounts being about 3% at the optimum. The latter averages between 1 and 1.5% at the optimum.

8. The strand succession is represented generally by the following zonation:

- Zone 1. *Salicornia rubra*
 S. utahensis
 Allenrolfea occidentalis
- Zone 2. *Suaeda erecta*
- Zone 3. *Distichlis spicata*
- Zone 4. *Suaeda* spp.
- Zone 5. *Sporobolus* spp.
 Atriplex spp.
 Sarcobatus vermiculatus
 Chrysothamnus spp.

9. Strand swamp types include *Scirpus americanus*, *S. paludosus*, *Potamogeton pectinatus*, *Ruppia maritima*, *Polypogon monspeliensis*, *Puccinellia nuttalliana*, and a variety of other plants.

10. The river deltas are modified by human agency and cultivation. Species of *Scirpus* predominate in most places while *Sparganium*, *Potamogeton*, *Typha*, and numerous salt marsh plants constitute a rich flora.

11. The strands of Great Salt Lake are bordered for their greatest extent by playas and alkaline plains with a few rocky headlands.

12. The soil is dominantly Jordan clay and Jordan loam with a clay or hardpan subsoil. The water table ranges from less than 3 feet to remote depths, but usually not far below 10 feet in most places.

13. The alkali relations are intimately connected with the water table. In general the percentage of alkali is roughly proportional to the depth of the permanent water, as follows:

Depth of the water table	Percentage alkali
3 feet or less.	3% or more
6 feet.	1-3%
10 feet.	0.25-1%

The H-ion concentration of the soils ranges from pH 8.0 to 9.4, the general average being pH 8.4 to 8.6.

14. The range of alkali toleration by the principal pioneer plants is:

	Maximum	Optimum	Minimum
Salicornia.	6%	2-3%	0.5-1%
Suaeda erecta.	4%	1-2%	0.25%
Allenrolfea.	3%	1-1.5%	0.25%
Distichlis.	2%	0.7-1%	0.25%

15. The vegetation of the playa-plains region is dominated by low shrubs of silvery gray and dark green color and numerous small annuals. There are a few algae, lichens, and mosses but no liverworts nor pteridophytes. Trees are absent.

16. Playas are invaded by the following succession of plants: *Salicornia rubra*, *S. utahensis*, *Suaeda erecta*, *Allenrolfea occidentalis*, *Distichlis spicata*, numerous small herbs in the Graminaceae and Cruciferae, and finally *Sarcobatus vermiculatus* and species of *Atriplex*.

17. Playas may be reclaimed almost exclusively by a single species. Homogeneous situations may show *Salicornia* flats, *Allenrolfea* flats, *Distichlis* meadows, or *Sporobolus* fields. In contrast the playas may be reclaimed by a mixed vegetation.

18. The alkaline plains show an average range of 0.6 to 1% alkali in the soil.

19. The following associations are well defined: greasewood-

shadscale, *Sarcobatus vermiculatus-Atriplex confertifolia*, forming the dominant vegetation; shadscale association, *Atriplex confertifolia*; *Kochia* flat association. Less well defined are the following plant communities: *Kochia-Eurotia*, *Kochia-Suaeda*, *Sarcobatus-Grayia*, and *Chrysothamnus* spp.

20. Dunes show a characteristic vegetation of *Sarcobatus*, *Atriplex* spp., *Chrysothamnus* spp., and a number of herbaceous species typical of sandy situations.

21. Salt marshes and sloughs show numerous algae and aquatic plants typical of mildly saline water. *Scirpus* spp., *Typha*, *Distichlis*, *Juncus*, *Eleocharis*, and a variety of herbs are the principal plants.

22. Hot mineral springs carry salt up to 5% and vary in temperature up to 61° C. Myxophyceae are the only plants. *Oscillatoria* spp. are dominant.

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